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EFFECTS OF NUTRIENT ENRICHMENT IN
A SUBALPINE OLIGOTROPHIC LAKE
IN SOUTHEASTERN WYOMING

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FINAL REPORT

EFFECTS OF NUTRIENT ENRICHMENT IN A SUBALPINE OLIGOTROPHIC
LAKE IN SOUTHEASTERN WYOMING

Prepared by

Michael Parker and Forrest Payne

Department of Zoology and Physiology
The University of Wyoming
Laramie, WY 82071

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INTRODUCTION

The purpose of this study was to investigate the effects of nutrient enrichment on the water quality and biological parameters of lakes in the Snowy Mountain Range of the Medicine Bow National Forest. Most of the lakes in the Snowy Range are probably oligotrophic (i.e., low in nutrients and low in zooplankton-phytoplankton production). Because of their low nutrient levels and low productivity we felt these lakes would be ideal to study the effects of nutrient enrichment.

The nutrients of interest in the study were phosphorus and nitrogen, primarily because they were found limiting in algal bioassays (Parker et al., 1977). Phosphorus, nitrogen and carbon are often considered as limiting factors in lake productivity. Based on the analyses of several investigators, carbon and nitrogen ordinarily will not be limiting in the long term (e.g., Schindler, 1974, 1975; Schindler and Fee, 1974; Parker, 1977). This is because the major source of phosphorus is the watershed, while nitrogen and carbon not only have the watershed as a source, but also the atmosphere. Thus, if phosphorus is in excess relative to carbon, then algal growth can deplete available carbon before phosphorus becomes limiting. However, as the carbon is reduced the partial pressure of CO_2 in the water is lowered, and additional CO_2 diffuses into the water from the atmosphere. This continued addition of carbon will eventually allow complete utilization of phosphorus, and phosphorus will become limiting (Schindler et al., 1972; Vanderhoef et al., 1972, 1974; Emerson et al., 1973; Schindler and Fee, 1974; Schindler, 1974, 1975; Emerson, 1975).

Similarly, when phosphorus is in excess compared to nitrogen, nitrogen fixation can occur producing more usable nitrogen and eventually phosphorus is depleted to limiting concentrations. There is evidence that when the N:P ratio is lowered, nitrogen fixing algae will occur in a lake even though they were previously absent or rare (Flett, 1972; Huong, et al., 1973; Megard and Smith, 1974; Schindler, 1974, 1975; Schindler and Fee, 1974).

In addition to phosphorus and nitrogen, we were interested in zooplankton, which are one intermediate link between algae and fish in the food chain. Alpine lakes, located above treeline, in general have low crustacean abundance and have a species richness ranging from one to four species (Patalas, 1964). Characteristic species are Diaptomus shoshone, D. arapahoensis, D. coloradensis and Holopedium gibberum. Diaptomus nudus, D. leptodus and D. rosea are characteristic of deep montane lakes and Cyclops vernalis and Ceriodaphnia quadrangula are characteristic of shallow montane lakes.

If nutrient levels increase, one generally expects increased algal production without an increase in diversity, or increased algal production with an increase in diversity. The first option would create more food items per zooplankter, but the second option could create more food items per zooplankter or decrease the number of food items because of a change in the quality of food items. A brief survey of the literature indicates that when a lake is enriched somewhat, zooplankton diversity remains relatively constant while abundance of zooplankton changes. Thus, Brooks (1969) noted in Lakes Erie and Michigan, a shift in the relative abundance of cladocerans, but not in cladoceran species diversity. The decrease in abundance of certain species in Lake Erie has been related to the increase

of facultative planktivores which selectively remove zooplankton (Beeton, 1965). Among the zooplankton of the Great Lakes, Patalas (1972) found twenty-seven species of crustaceans in the summer plankton (fourteen copepods and thirteen cladocerans). Of these, nine copepods and six cladocerans were common to all the lakes and eleven copepods and ten cladocerans were common to Lake Huron (oligotrophic), Lake Erie (eutrophic) and Lake Ontario (mesotrophic).

The effects of enrichment on trout growth was investigated by Baxter (1957, 1958) in alpine Lake Marie, which is located in the Snowy Range. On 5 July 1955 Lake Marie was fertilized from boats by the addition of 1000 pounds of 12-24-0(N-P-k) mixture of a commercial fertilizer. Between 5 July 1956 and 7 September 1956 an additional 1350 pounds was added by placing 50 pound burlap sacks of fertilizer into the inlet streams. The concentration of phosphorus was initially high but soon dropped to less than .01 ppm. The abundance of the rotifer Keratella cochlearis increased after fertilization, but the cladocerans Daphnia and Ceriodaphnia showed little or no increase. However, it is not known to what extent nutrients were lost to the sediments. More importantly, the effect of short circuiting on the nutrients was not known. Short circuiting occurs when the water coming into the lake passes through rapidly with little mixing (Wagner, 1971).

The study upon which this investigation is based was conducted on Great Central Lake in British Columbia (Parson et al., 1972; Barraclaugh and Robinson, 1972; LeBrasseur and Kennedy, 1972; Stockner, 1977). Five tons of fertilizer were added to the lake per week between May and October, 1970. The purpose was to enhance the size of juvenile sockeye salmon

leaving the lake. The larger the size of juveniles the better their chances of survival in the open ocean, and the greater the numbers of adults returning to the lake. The investigators found that surface primary production increased tenfold and primary production in the euphotic zone increased twofold (Parsons et al., 1972). The increase in primary production resulted in an average zooplankton biomass of greater than 5 g m^{-2} , which was ten times greater than for a comparable period prior to fertilization in 1967 (Le Brasseur and Kennedy, 1972).

In our experiment we hope to determine if similar increases in nutrient loading will increase primary production, with a resultant increase in zooplankton production. We will infer the effects of an increase in zooplankton production upon trout production. Our approach is to employ in-situ microcosms, each receiving a different areal loading rate over a three month period.

DESCRIPTION OF STUDY SITE

Big Brooklyn Lake (R79, T16, S10) was selected as the study site. It is characteristic of many of the lakes in the Snowy Range in that it is low in nutrients, has an inlet and outlet, and is relatively deep (12 meters). However, the primary reason for its selection is that it receives, perhaps, the greatest impact from recreational activities of any lake in the Snowy Range. Secondary homes surround its shoreline and in addition there is a campground and a dirt road that encircles the lake. The lake covers $92,435 \text{ m}^2$ with a volume of $299,308 \text{ m}^3$ (Parker et al., 1977). It is at an elevation of 3,215.64 m. Approximately 65% of the lake is shoal with the rest of the bottom being made up of boulders, gravel and sand (Kanaly, 1973). Figure 1 is a morphometric map of Big Brooklyn Lake.

The total discharge of Big Brooklyn is $1,576,800 \text{ m}^3 \text{ yr}^{-1}$. The annual phosphorus input is $15,840 \text{ g yr}^{-1}$ and output is $10,740 \text{ g yr}^{-1}$. The lake retained approximately 32% of the phosphorus loaded. Areal loading equaled $0.17 \text{ g m}^{-2} \text{ yr}^{-1}$ and the lake was turned over approximately six times (Parker et al., 1977).

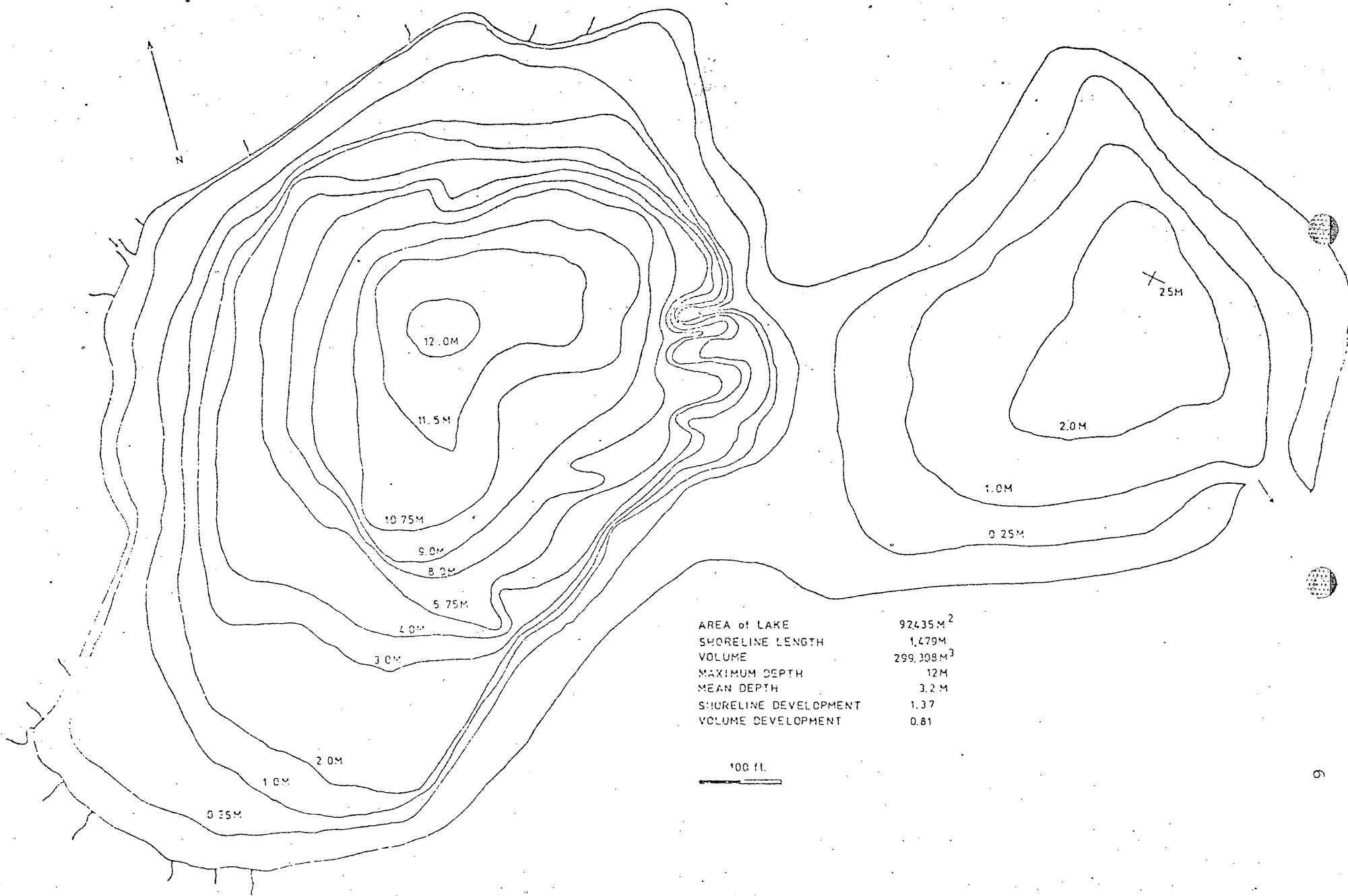


Figure 1. Morphometric map of Big Brooklyn Lake.

MATERIALS AND METHODS

Between 18 July 1978 and 3 November 1978 field experiments using in-situ microcosms were conducted in Big Brooklyn Lake. The design of the microcosm was based on work by Goldman (1962) and Goldman and Carter (1965). Each microcosm consisted of a four mil polyethylene sheet heat sealed and taped into the shape of a tube (Figure 2). To keep the tube open, wire hoops were placed at one meter intervals. These hoops were fastened to the outside of the tube by first placing two to three marbles in the tube and then tying a nylon rope around the polyethylene and the marbles, making a small ball. The nylon rope was then tied around the wire. The marbles were used to spread potential point stress over a wider area. To keep the tube upright, plastic milk bottles were taped to wire hoops to form a float assembly. The polyethylene tube then was pulled through the center of the float assembly and folded down over the outside of the milk bottles. Finally, a nylon rope was run through grommets in the top end of the polyethylene tube and tied around the milk bottles. The bottom of the tube was closed by a nylon rope running through grommets and drawn up like the string on a laundry bag. The rope was then placed through a cinder block, which served as an anchor, and tied off at the surface to the float assembly. All microcosms were in place by 27 July. The placement of the tubes was accomplished from a one man raft, a four man raft and a canoe. Access by road was not possible until August 1; prior to then all materials had to be backpacked one to one-half mile to and from the lake.

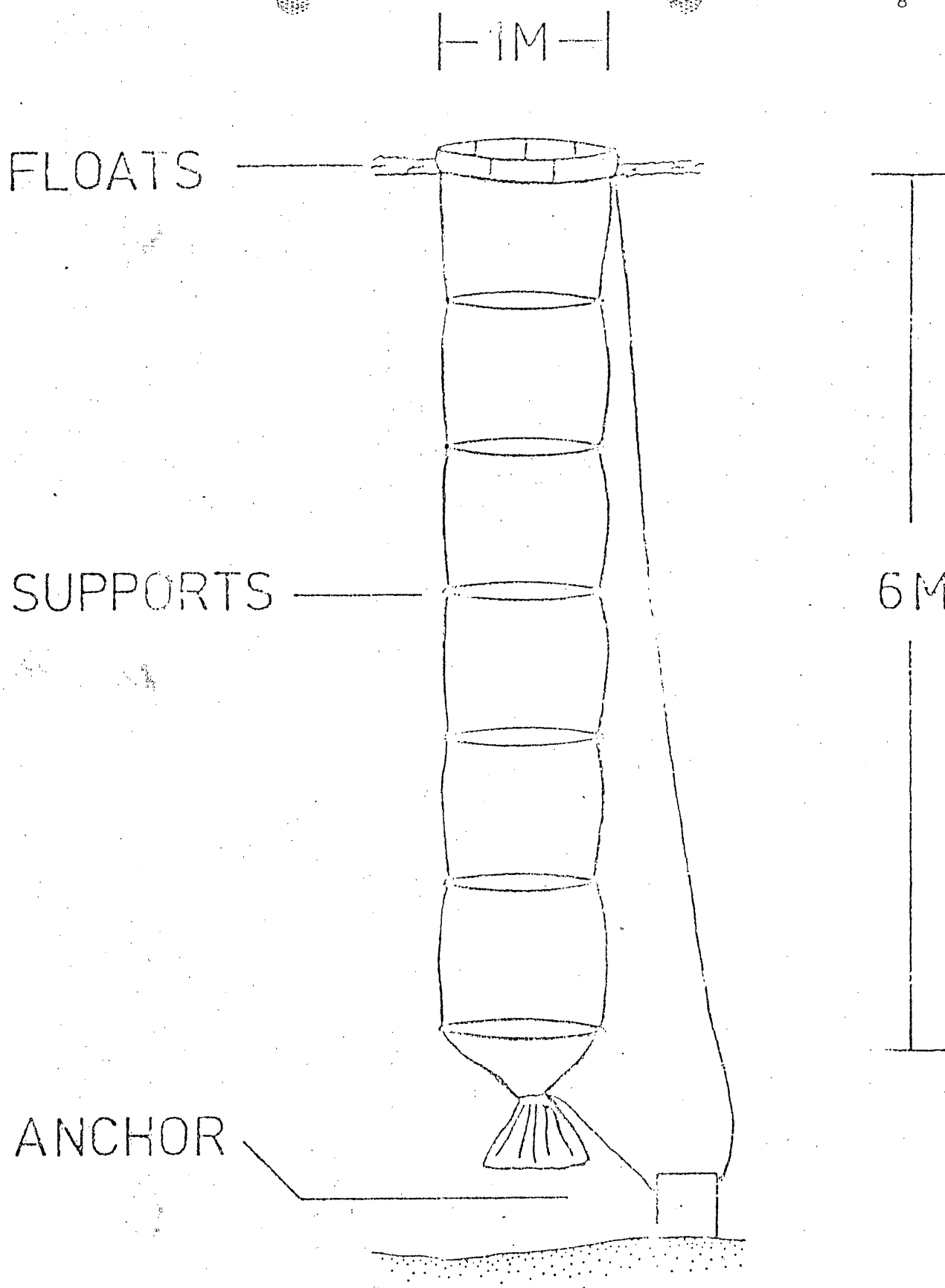


Figure 2. A schematic of a microcosm in Big Brooklyn Lake.

Each of the microcosms received a different level of nutrient loading. The reasoning behind giving each microcosm a different load was to gain as much information as possible in one summer. The phosphorus loading rates were based on the areal loading rate of $0.17 \text{ g m}^{-2} \text{ yr}^{-1}$ determined by Parker, et al. (1977) for Big Brooklyn Lake. Nitrogen loads were based on the ratio of seven parts nitrogen to one part phosphorus. This ratio has been established as the optimum ratio for algal growth (Wetzel, 1975). Phosphorus was added as potassium phosphate dibasic and nitrogen added as sodium nitrate. The following loading rates were to be used in the experiments:

<u>Microcosm</u>	<u>Yearly Loading Rates</u>
2X	2X the normal load of phosphorus
2X+N	2X the normal load of phosphorus plus nitrogen
4X	4X the normal load of phosphorus
4X+N	4X the normal load of phosphorus plus nitrogen
8X+N	8X the normal load of phosphorus plus nitrogen
Control	Control ($\approx 0.17 \text{ g P m}^{-2} \text{ yr}^{-1}$)

We intended to add nutrients to the tubes 48 times during a three month period, or 1/48 of the total amount four times per week.

To mimic the flushing of the lake, the microcosms had lake water pumped into them. As water was pumped in an equal amount flowed out through the grommets. The rate of pumping was calculated to overturn the microcosm every two weeks, or six times during the course of the experiments. A Guzzler hand pump (Dart Union Co.) was used for pumping.

Water samples for chemical determinations were collected using a Kemmerer sampler. One liter samples were taken at the surface, two meters and four meters in each microcosm and in the lake. The three samples were mixed in a three liter plastic water bottle, packed in ice and then taken back to the laboratory for analysis.

Physical-chemical data were collected weekly during the project.

Temperature was measured with a Whitney underwater thermometer. Secchi disc readings were taken following the methodology of Lind (1974). The forms of phosphorus measured were: 1) total filterable and nonfilterable phosphate (total phosphorus); 2) total filterable and nonfilterable orthophosphate; 3) total filterable (dissolved) phosphate; 4) filterable (dissolved) orthophosphate (orthophosphate); 5) and total nonfilterable phosphate (particulate phosphate) (APHA, 1976). Persulfate digestion and ascorbic acid were the respective methods used for digestion and color development (APHA, 1976).

Nitrate-nitrogen was measured by the cadmium-reduction method, ammonia-nitrogen by the phenate method, and dissolved oxygen by the azide modification method (APHA, 1976). For hardness, calcium, and alkalinity determinations we used the methodology outlined in Lind (1974). A Sargent-Welch pH meter was used for measuring pH and a Hach conductivity meter for measuring conductivity. Dissolved carbon dioxide was calculated indirectly using the method in Rainwater and Thatcher (1960). A Beckman DU spectrophotometer was used for all colorimetric determinations except nitrate-nitrogen, which was determined on a Bausch and Lomb Spectronic 600. Vertical illumination readings were taken at meter and half meter intervals using a submersible photometer (Gemware Precision Instruments). The procedure described in Lind (1974) was used in measuring vertical illumination and to calculate attenuation coefficients. Chlorophyll a determinations were made following the methodology described in Standard Methods (APHA, 1976).

Zooplankton samples were collected from 0 to 5 m at 1 m intervals using a Van Dorn water sampler. Under adverse field conditions (i.e.,

wind, waves, or cold) a Kemmerer sampler was used because of ease of cocking and speed. Three liters of water were obtained at each depth for a total of 18 liters for each sampling of the microcosms and the lake. The samples were strained through a No. 25 Wisconsin plankton net and sufficient ethanol was added to the sample for a final concentration of 70% ethanol. One milliliter subsamples of the concentrated zooplankton sample were enumerated in a Sedgewick-Rafter cell. The number of zooplankton in each taxa found in the counting chamber was recorded. Each concentrated zooplankton sample had two one milliliter samples removed and counted. The two counts were then averaged to calculate the numbers of animals liter⁻¹. All animals were measured using an ocular grid calibrated with a stage micrometer. The longitudinal axis of copepods was measured excluding setae on the caudal rami. Cladocerans were measured from the anterior end of the head to the posterior end of the spine, if present, on the carapace. Identification of the organisms was made using Pennak (1953).

Phytoplankton samples (750 ml) were taken at the surface, two meters and four meters. The samples were mixed in a plastic bucket and a one liter subsample removed. The subsample was preserved in Lugol's solution (Ward and Whipple, 1956). In the laboratory the samples were passed through a series of sedimentation chambers until about 70 ml of liquid plus phytoplankton was left. Periphyton collections were obtained following methodology described in Standard Methods (APHA, 1976). Microscope slides were placed in rubber stoppers with slits cut into the sides. The stoppers were suspended in the microcosms from a fishing bobber attached to the float assembly. One stopper was placed in each microcosm and each stopper held four slides. The phytoplankton and the periphyton samples have not yet been analyzed.

Several problems occurred during the study which are worth mentioning. The raft used was a two man raft. Because it sat low in the water we did not attempt to collect whenever the lake had considerable wave action. Big Brooklyn Lake is situated directly in front of a pass between Medicine Bow and Brown's Peak, and apparently this pass creates a wind funnel which can make the lake quite choppy. On several occasions sampling was cancelled because the wind made it impossible to row away from the launching site. Also, under windy conditions, when the raft was tied to the microcosm's float assembly for collecting, the microcosm would be pulled from a vertical to an angular position which made it extremely difficult to trigger either the Van Dorn or Kemmerer sampler, and to take Secchi disc readings. Apparently, the wind action was also great enough to move the microcosms from their original position. Whatever the cause of this movement, the microcosms were not damaged. The lack of damage was determined by visual inspections using scuba gear.

Statistics

The primary statistical test used was the paired t-test (Mendenhall, 1975). In addition to the use of t-tests certain parameters were tested for correlation via linear regression analysis (Neter and Wasserman, 1974). All calculations were made with a Texas Instrument 58. Differences were considered to be significant when $\alpha \leq 0.20$. An $\alpha = .20$ means the decision could be wrong 20% of the time. We choose to accept significant differences when $\alpha \leq .2$, rather than the more common standard of $\alpha \leq .05$ based on discussions with Lyman McDonald, the Zoology Department's statistician. He convinced us there should be three categories of statistical decision, especially in field research: when $\alpha \leq .05$ the decision is "yes there is a significant difference"; when $0.05 < \alpha \leq 0.2$ the decision

is "maybe there is a trend indicated"; and when $\alpha > .2$ the decision is "no there is not any significant difference."

RESULTS

Nutrient Loads

Although the experiments was designed to add nutrients four times per week for three months we were unable to follow this schedule because of inclement weather. Often we loaded two, three or four day's nutrient input in one day in an attempt to stay on the weekly loading schedule. Table 1 shows the actual and predicted area loading for dibasic potassium phosphate and sodium nitrate.

Flushing

Inclement weather prevented the six times flushing of the microcosms during the study. Computations revealed that the tubes were flushed approximately two times. However, wave and wind action added water to the microcosm and the total amount of water from this source was probably significant. Often extreme winds would curl the lip of the tube into the water allowing free access of surface waters.

Temperature

Water temperature in the lake ranged from a minimum of 48°C (bottom) to a maximum of 14.6°C (surface; Figure 3). Note that between 10 August 1978 and 14 August 1978 the temperature of the lake decreased in the upper seven meters of water. It was during this period that the lake was constantly receiving high winds which created waves of approximately two to three feet high. The wave action plus cold weather caused the observed temperature reduction. Before the beginning of the winds, the metalimnion

Table 1. The actual and predicted loading rates for dibasic potassium phosphate ($\text{g m}^{-2} \text{yr}^{-1}$) sodium nitrate ($\text{g m}^{-2} \text{yr}^{-1}$).

Microcosm	Dibasic Potassium Phosphate		Sodium Nitrate		Predicted Load	Actual Load
	Predicted	Actual	Predicted	Actual		
Control			(Control)			
2X	1.06	.83			2X	1.75X
2X+N	1.06	.93	6.10	5.32	2X	1.75X
4X	3.09	2.64			4X	3.4X
4X+N	3.09	2.64	17.86	15.63	4X	3.4X
8X+N	7.06	5.70	40.80	32.25	8X	6.46X

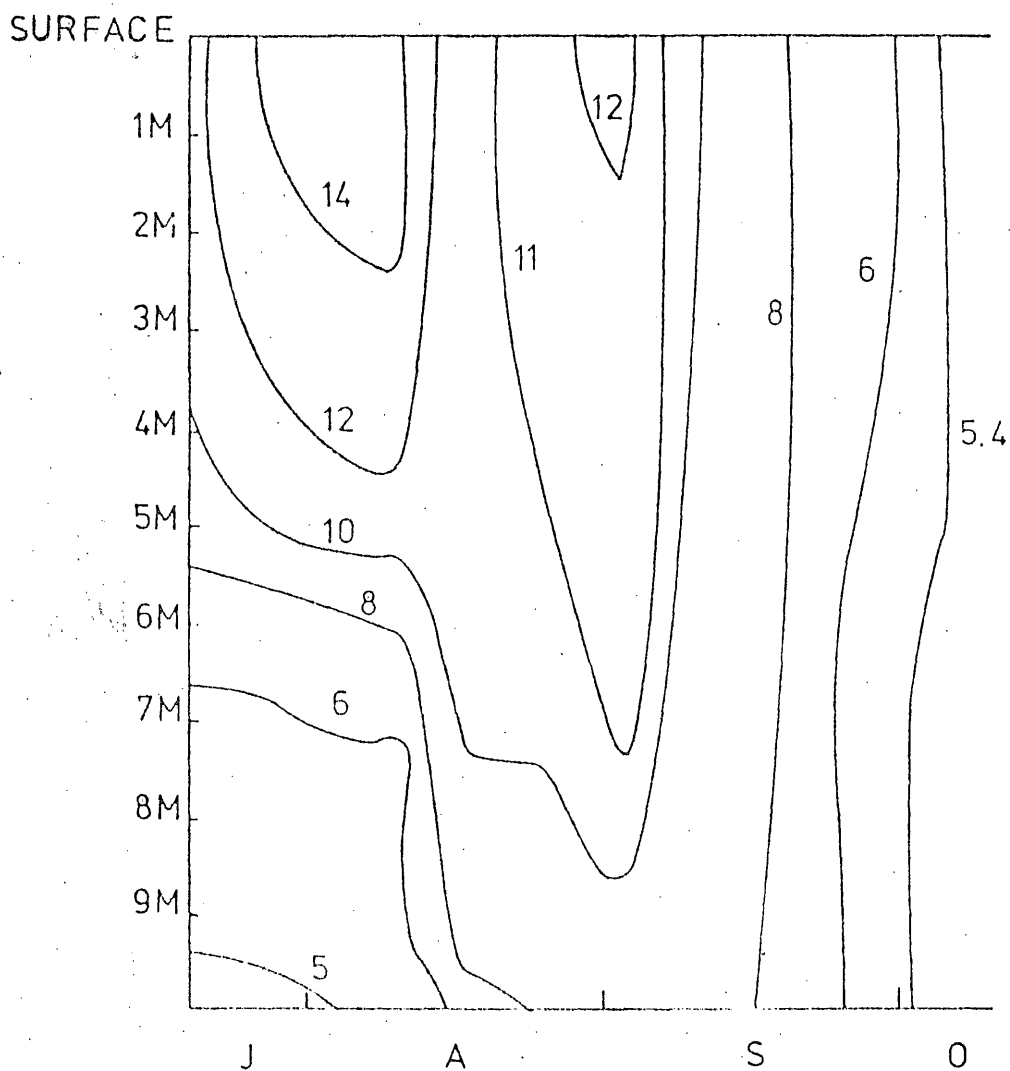


Figure 3. Temperature data for Big Brooklyn Lake from July through October 1978. The temperature represented by each isotherm is indicated in °C.

was between two and three meters, but after the wind and wave action the metalimnion decreased to the seven to nine meter level. The temperature of the microcosms was always similar to that of the lake. Appendix A presents the temperature data for both the microcosms and the lake.

Because we pumped lake water into the microcosms from the upper two meters we were concerned that the temperature profile in the microcosm might be changed. However, a paired t-test showed no significant difference in the temperature profile of the microcosms before and after pumping.

Secchi Disc

Figure 4 shows the Secchi disc readings from each microcosm and the lake. The numerical data are presented in Appendix B. All microcosms and the lake were compared to each other using a one-tailed paired t-test (Table 2). A one tailed test was justifiable because we expected an increase in nutrients to result in an increase in algal numbers, with a resultant decrease in Secchi disc readings (Carlson, 1977). In general the direction of decreased Secchi disc readings (i.e., increased material in the water column) was toward the microcosms receiving the greatest nutrient load.

Alkalinity

Values of alkalinity (Appendix C) ranged from a low of 13.9 to a high of $32.2 \text{ mg CaCO}_3 \text{ l}^{-1}$ (Figure 5). These values are somewhat less than those often encountered in natural waters (45 to $200 \text{ mg CaCO}_3 \text{ l}^{-1}$; Lind, 1974). A two tailed paired t-test did not reveal any significant differences between microcosms or between microcosms and the lake.

Hardness

Hardness is a characteristic of water representing the total concentration of calcium and magnesium ions, and is often expressed as milligrams

Table 2. Levels of significance between treatments using a one-tailed paired t-test.

		Treatment with decreased Secchi disc measurement						
		Lake	Control	2X	2X+N	4X	4X+N	8X+N
Treatments with increased Secchi disc measurement	Lake	$\alpha=.005$	$\alpha=.005$	$\alpha=.005$	$\alpha=.005$	$\alpha=.005$	$\alpha=.005$	$\alpha=.005$
	Control							
	2X						$\alpha=.1$	$\alpha=.1$
	2X+N	$\alpha=.1$						$\alpha=.1$
	4X	$\alpha=.1$					$\alpha=.1$	$\alpha=.1$
	4X+N							
		8X+N						

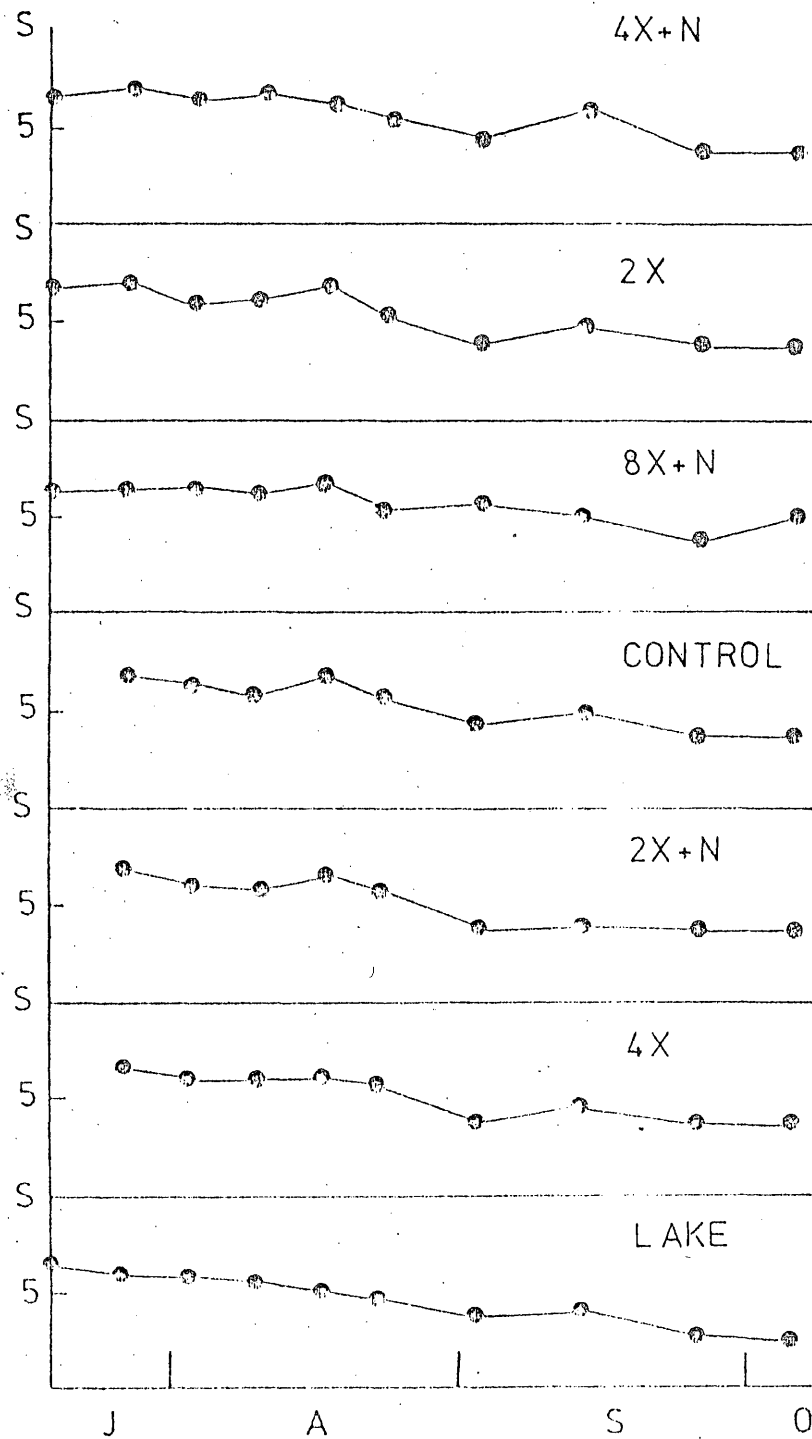
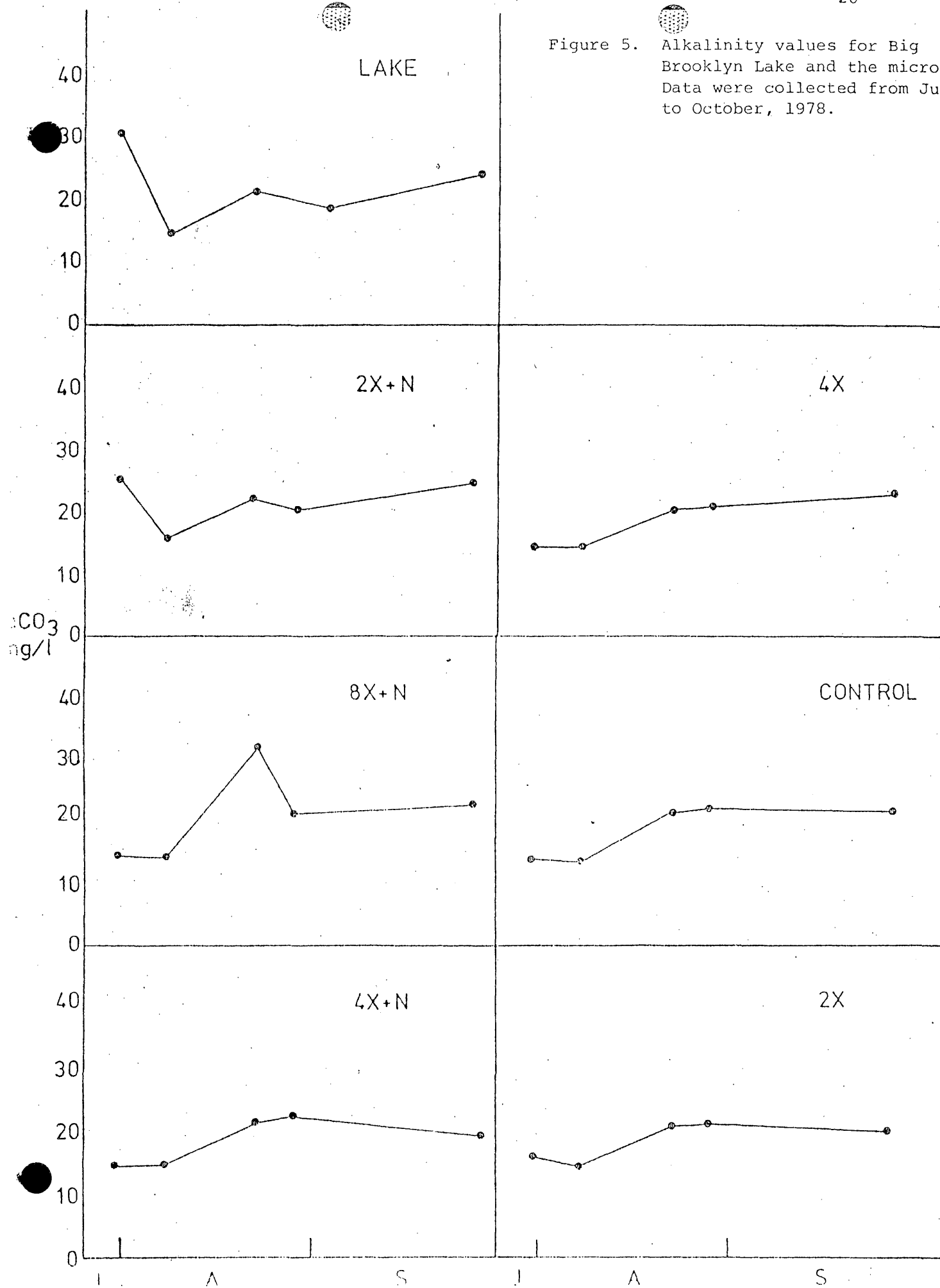


Figure 4. The depths to which a Secchi disc was visible in the microcosms and the lake. S is the surface and 5 represents the 5 meter level. Data are for July to October, 1978.

Figure 5. Alkalinity values for Big Brooklyn Lake and the microcosms. Data were collected from July to October, 1978.



of CaCO_3 per liter. If the hardness is equal to or less than the sum of the carbonate and bicarbonate alkalinities then it is called carbonate hardness, and other cations are insignificant compared to Ca^{++} and Mg^{++} . Our procedure was unable to detect hardness, thus the lake is extremely low in calcium and magnesium ions.

Calcium

As discussed above calcium appeared to be present in low concentrations and our method detected none.

pH

The pH of the various tubes ranged between 8.25 and 7.1 (See Appendix D for the data). Because the pH values were so similar we performed only enough two tailed paired t-tests to be confident that there was no significant differences between microcosms and between microcosms and the lake.

Dissolved Carbon Dioxide

Microcosm 8X+N had less dissolved carbon dioxide than all other microcosms (Figure 6). The concentration of CO_2 in the 8X+N microcosm was significantly less than that in the 4X, 2X ($\alpha < 0.1$) and 2X+N ($0.1 < \alpha \leq 0.2$) microcosms. Microcosm 4X+N and the control had significantly more CO_2 than the 8X+N microcosm at the $\alpha < .02$ and $\alpha < .05$ respectively. CO_2 in the microcosm with the second highest load (4X+N) was significantly less than the control ($\alpha < .2$). Although not quite significant, the 4X+N treatment indicated the same trend as 8X+N (i.e., lesser CO_2 associated with greater loading). The data on CO_2 concentrations are tabulated in Appendix E.

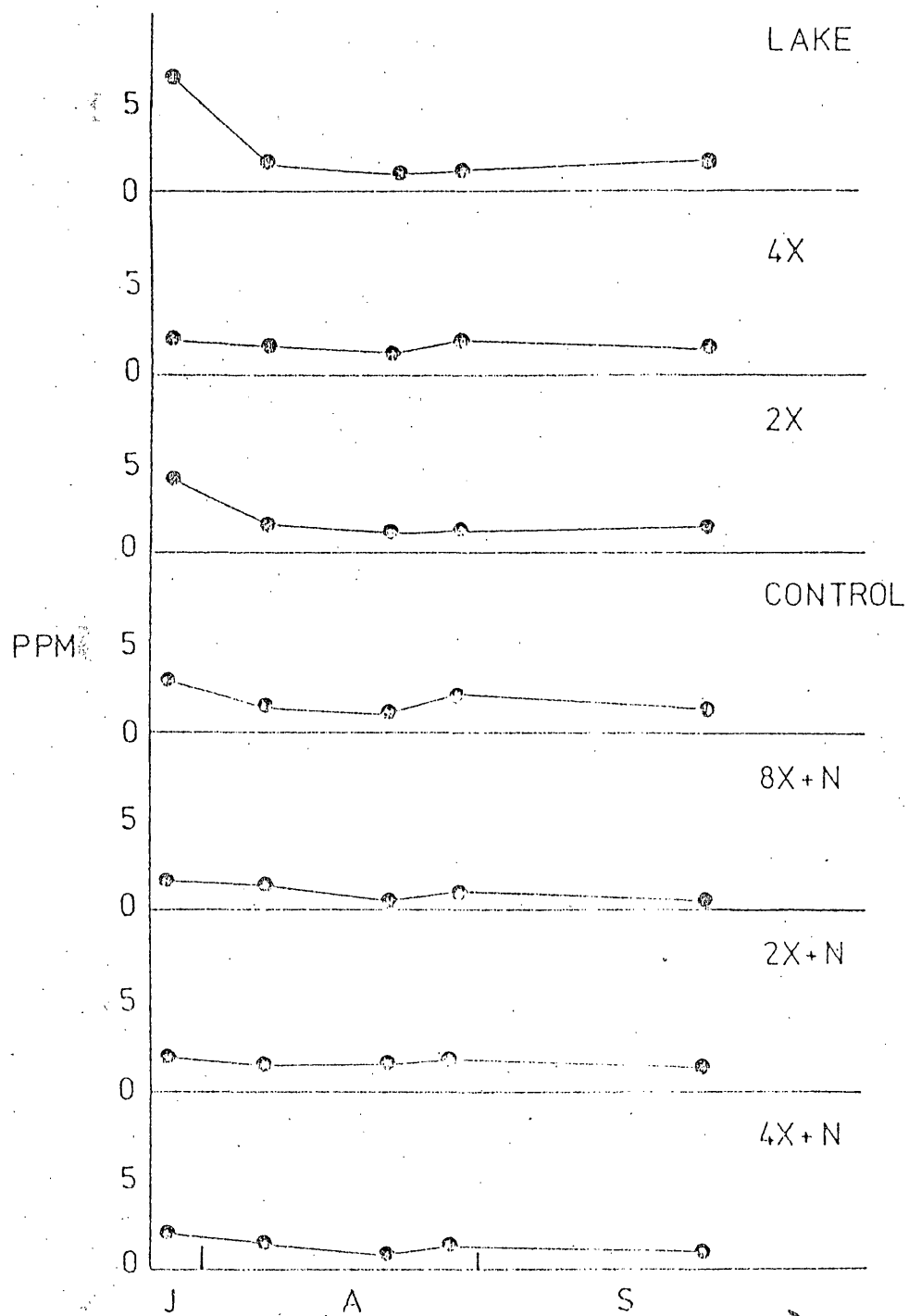


Figure 6. Concentrations of dissolved CO_2 in the microcosms and the lake. The data were collected from July to September, 1978.

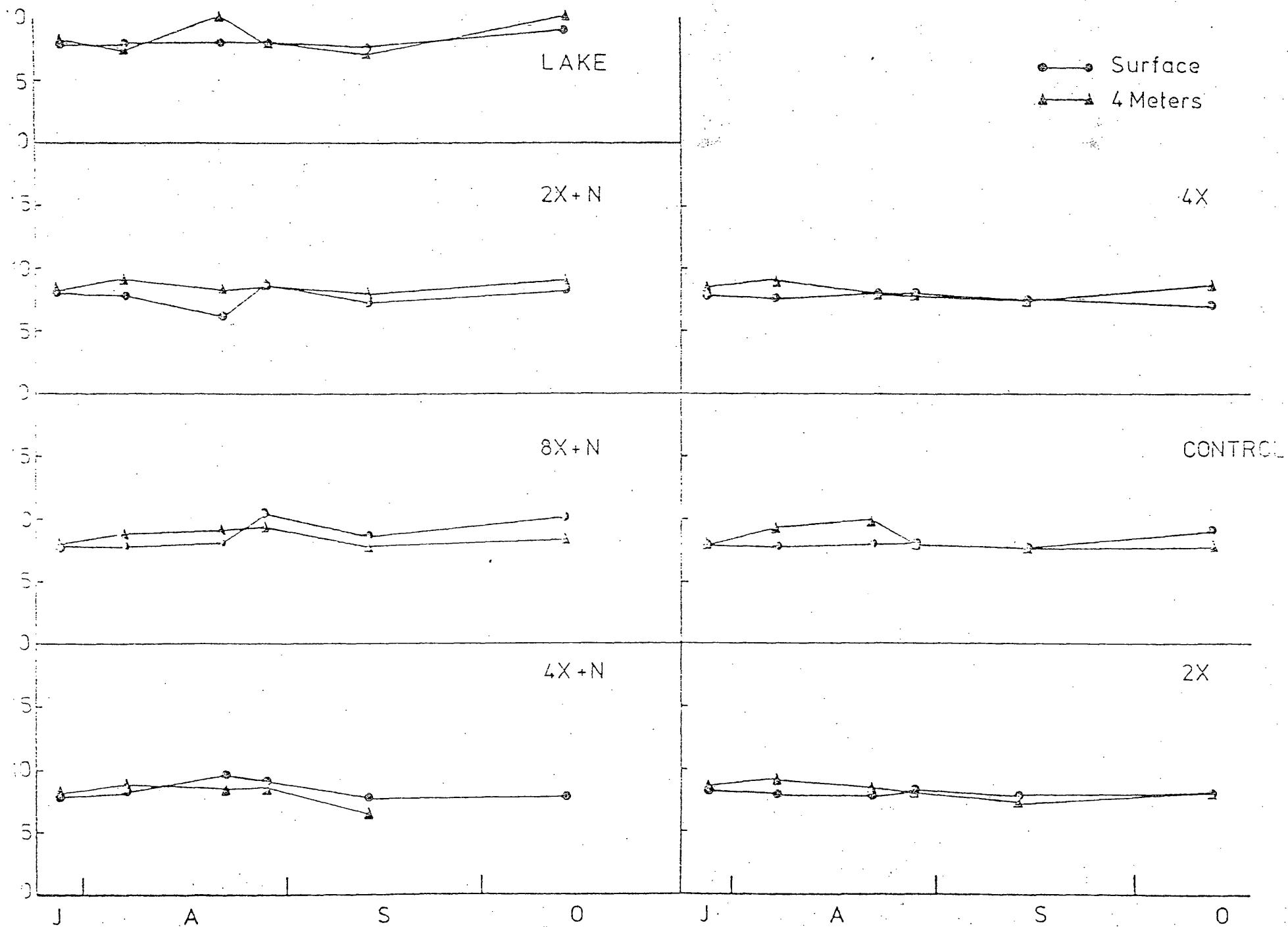


Figure 7. Dissolved oxygen concentrations (ppm) in Big Brooklyn Lake and the microcosms, from the surface and the four meter level. Data were collected from July to October, 1978.

Dissolved Oxygen

The concentration of dissolved oxygen at the surface of microcosm 8X+N was significantly greater from all other microcosms except 4X+N and the lake (Figure 8, Appendix F). The significance level was $\alpha < .05$ for 8X+N compared to 2X+N and $\alpha < .1$ for 8X+N compared to 4X. For all other between microcosm comparisons the significance level was $\alpha = .2$. Although it was expected that 4X+N would also have more dissolved oxygen than microcosms with less loading, this was not the case. Among all comparisons, oxygen in microcosm 4X+N was only significantly greater ($\alpha < .1$) from oxygen in 4X. Oxygen in microcosm 2X was significantly greater than oxygen in 4X ($\alpha = .2$). The only other significant differences between microcosms occurred with samples from the four meter level. Oxygen in microcosm 2X+N was significantly greater than in 4X ($\alpha < .1$), and oxygen in 2X+N was significantly greater than 4X+N ($\alpha < .1$).

Conductivity

Specific conductivity is a measure of waters' capacity to conduct an electric current. The values obtained during the investigation are presented in Appendix G. Significant differences between the values of conductivity from all possible comparisons are presented in Table 3. Thus, based on a two-tailed paired t-test, all microcosms were significantly different from the control, but only at $\alpha = .2$. Also, conductivity in microcosm 4X+N was significantly greater from that in all other microcosms and the lake.

Phosphorus

Our methods measured five forms or fractions of phosphorus in lake water. Data from the three most important fractions, total phosphorus, ortho-phosphorus and particulate phosphorus are presented in Figures 8 through 13. Data on all fractions are presented in Appendix H.

Table 3. Levels of significance for two tailed paired t-tests evaluating differences in conductivity.

		Treatments with increased conductivity						
		Lake	Control	2X	2X+N	4X	4X+N	8X+N
Treatments with decreased conduc- tivity	Lake						$\alpha=.05$	
	Control			$\alpha=.2$	$\alpha=.2$	$\alpha=.2$	$\alpha=.02$	$\alpha=.2$
	2X						$\alpha=.1$	
	2X+N						$\alpha=.2$	
	4X+N							
	8X+N						$\alpha=.005$	

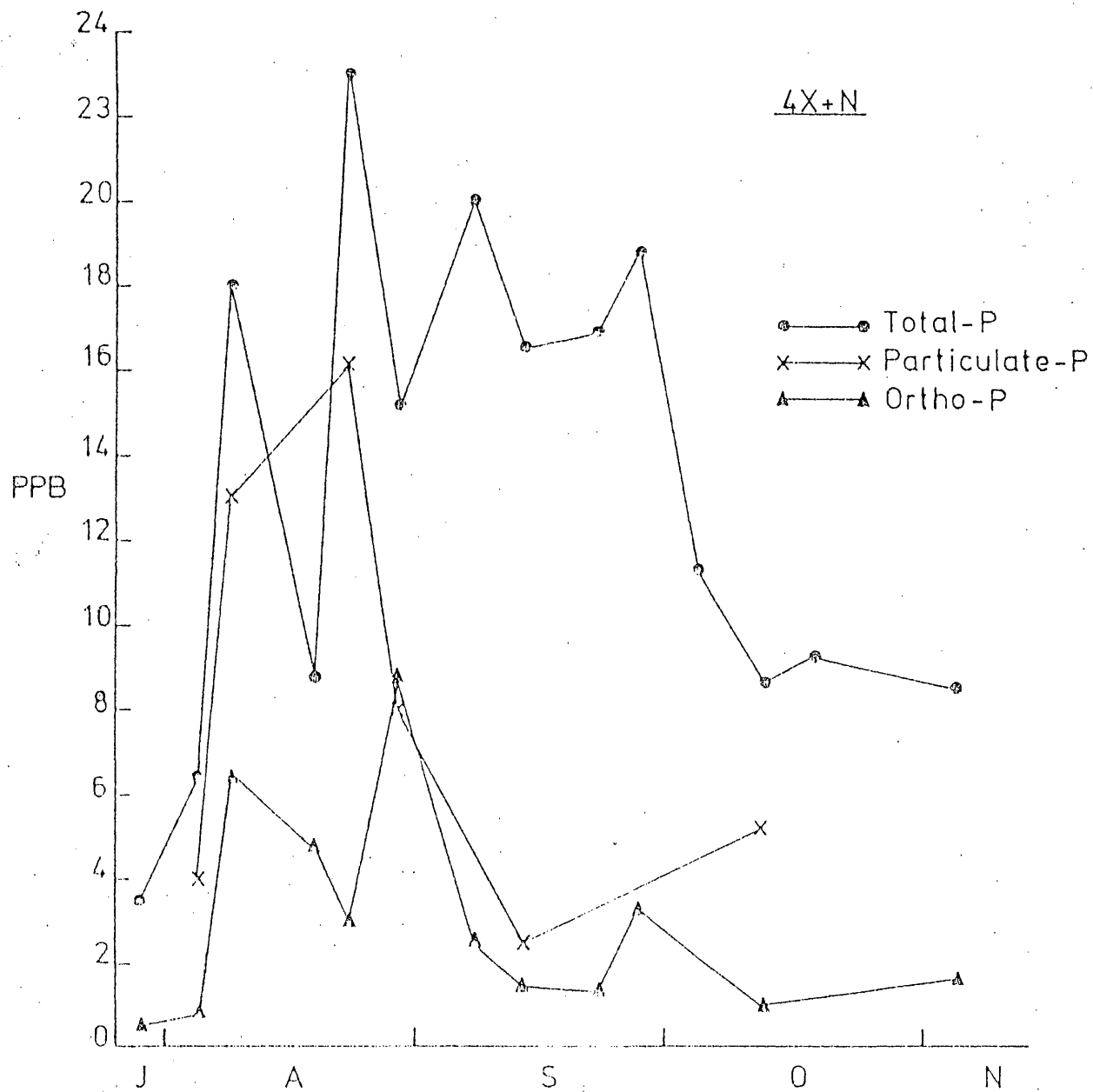


Figure 8. Total phosphorus, particulate phosphorus and ortho phosphorus concentrations in microcosm 4X+N between July and November 1978.

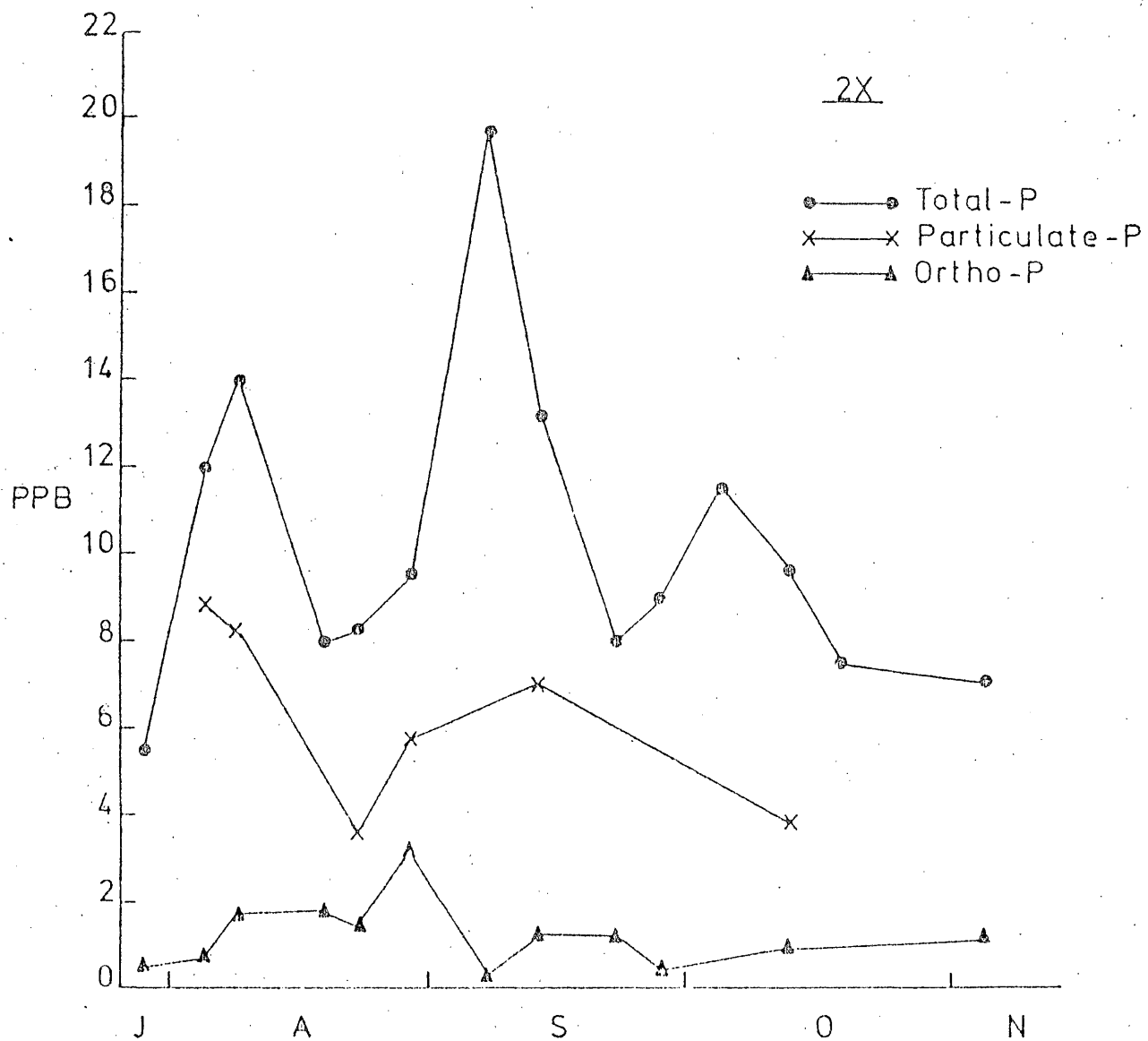


Figure 9. Total phosphorus, particulate phosphorus and ortho phosphorus concentrations in microcosm 2X between July and November 1978.

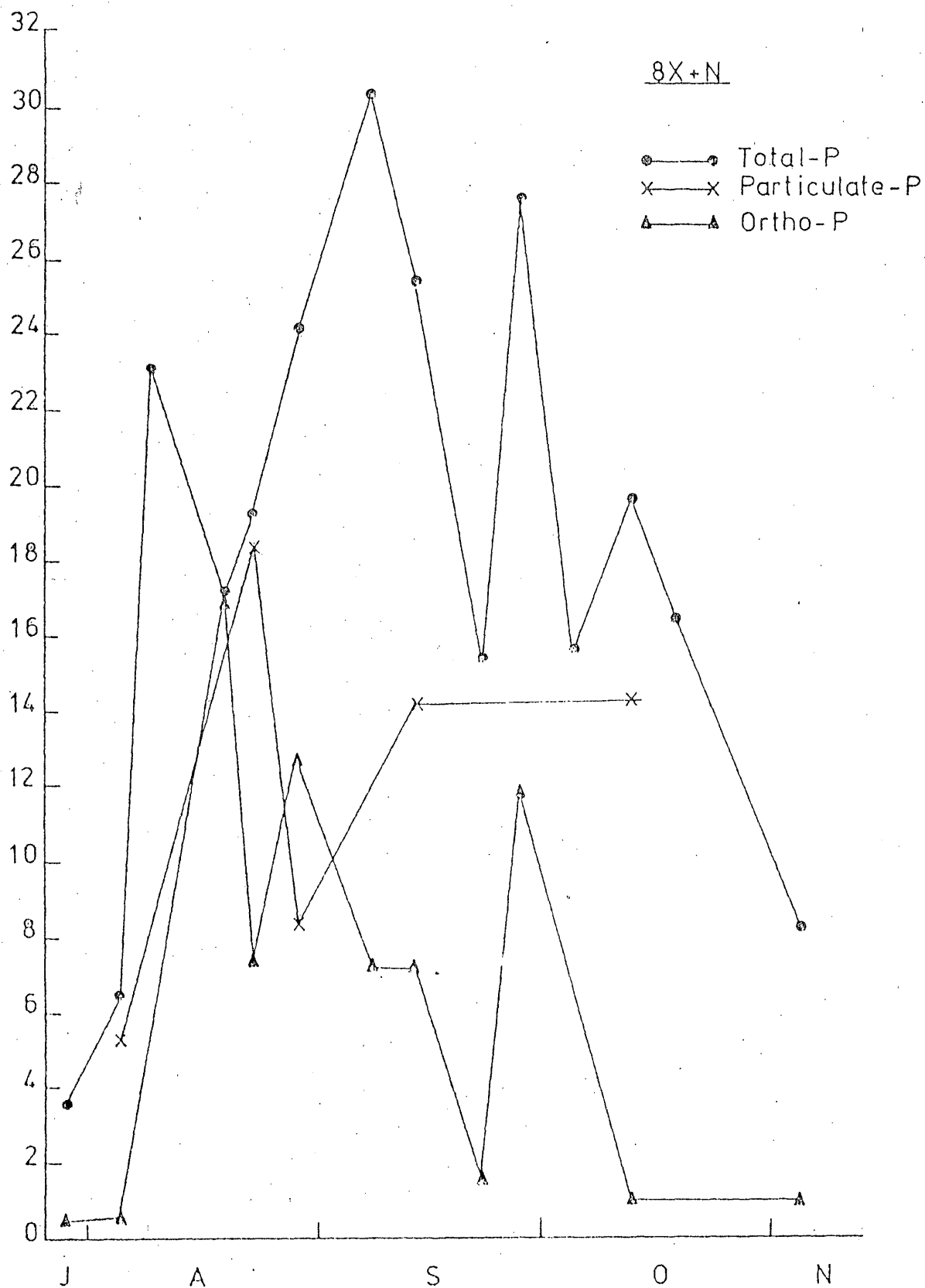


Figure 10. Total phosphorus, particulate phosphorus and ortho phosphorus concentrations in microcosm 8X+N between July and November 1978.

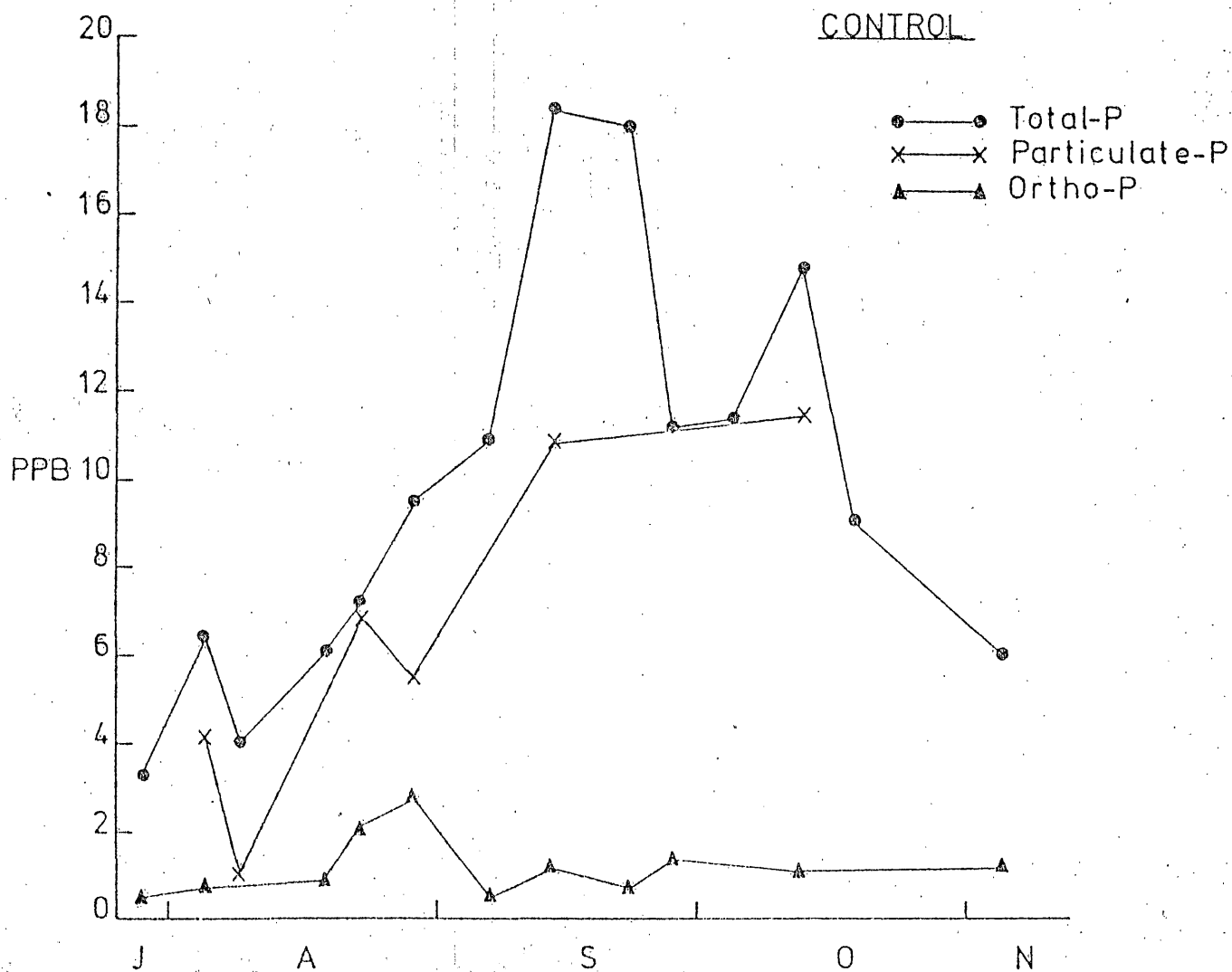


Figure 11. Total phosphorus, particulate phosphorus and ortho phosphorus concentrations in the control microcosm between July and November 1978.

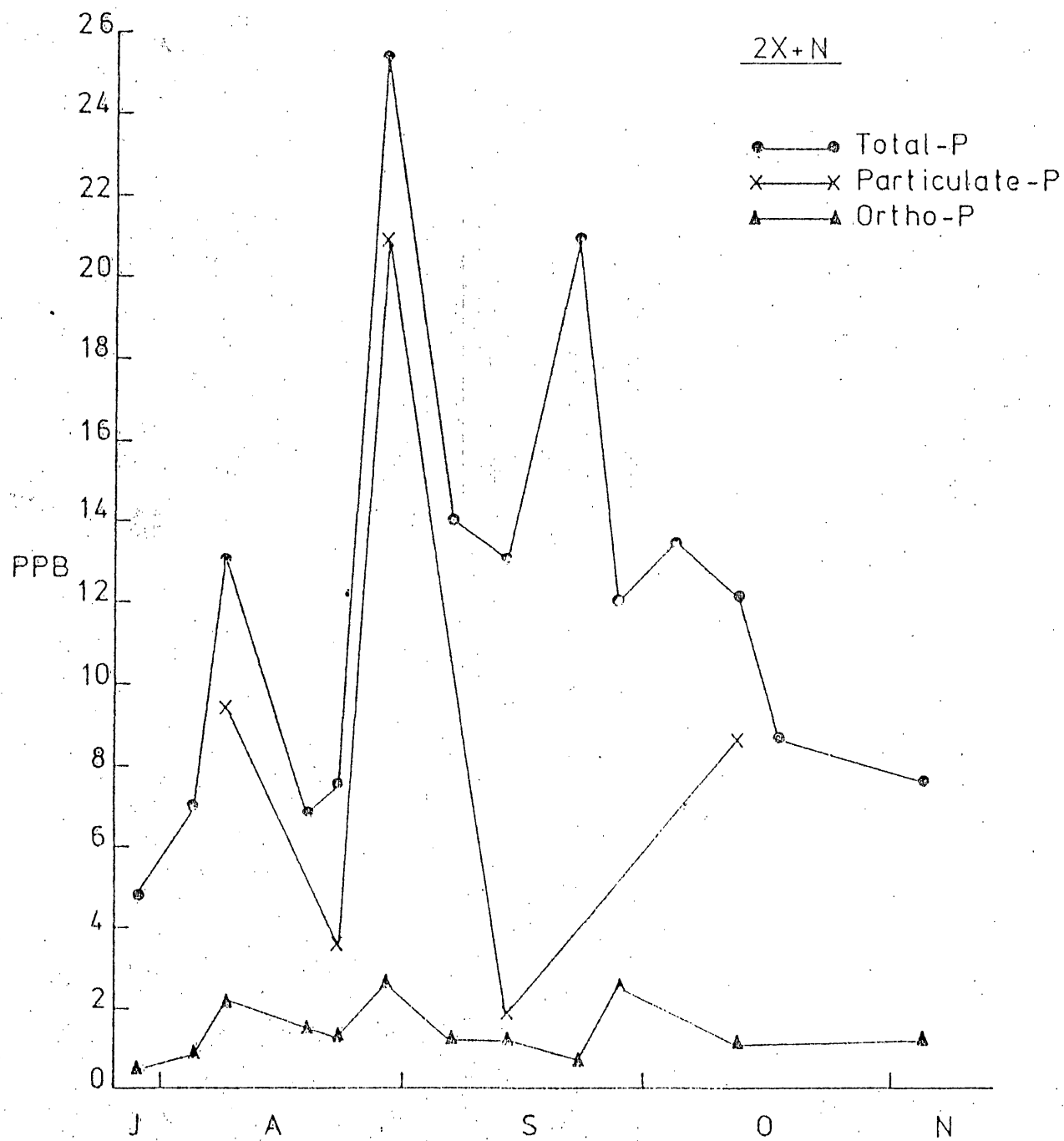


Figure 12. Total phosphorus, particulate phosphorus and ortho phosphorus concentrations in microcosm 2X+N between July and November 1978.

For each microcosm we correlated ortho-phosphorus with total phosphorus and particulate phosphorus with total phosphorus. None of the correlations between ortho-phosphorus and total phosphorus were significant. However in microcosms 4X+N, 2X, control, 2X+N and the lake there was a positive correlation between the particulate phosphorus and total phosphorus. The correlation coefficients (r) equaled .751 in 4X+N, .853 in 2X, .917 in the control, .88 in 2X+N and .735 in the lake. The correlations were significant at $\alpha = .05$ level. To see if we could get a better correlation between particulate phosphorus and total phosphorus we pooled the data from each microcosm. The correlation coefficient was .693 with a regression equation of $6.7413 + 8.628$ (total phosphorus concentration) = (particulate phosphorus concentration). Testing the hypothesis $H_0 : r = 0$ as opposed $H_1 : r \neq 0$ using a t statistic we rejected H_0 in favor of H_1 at the $\alpha = .05$ level.

Microcosm 8X+N had significantly more total phosphorus than all the other microcosms and the lake ($\alpha = .01$). The total phosphorus concentration in microcosm 4X+N was significantly greater than the total phosphorus concentration in the lake ($\alpha = .02$), the control ($\alpha = .0$) and the microcosm 2X ($\alpha = .10$). Microcosm 4X had significantly more total phosphorus than did the lake ($\alpha = .01$), the control ($\alpha = .01$) and 2X ($\alpha = .10$). In general, the trend of greater to lesser total phosphorus concentrations was from the highest load (8X+N) to the second highest load (4X). The same trend was also observed for orthophosphate.

Microcosm 8X+N had significantly more particulate phosphorus than the control, 4X, the control ($\alpha = 0.10$), and 4X+N ($\alpha = .02$). These levels of significance suggest a trend of more particulate phosphorus associated with greater loadings.

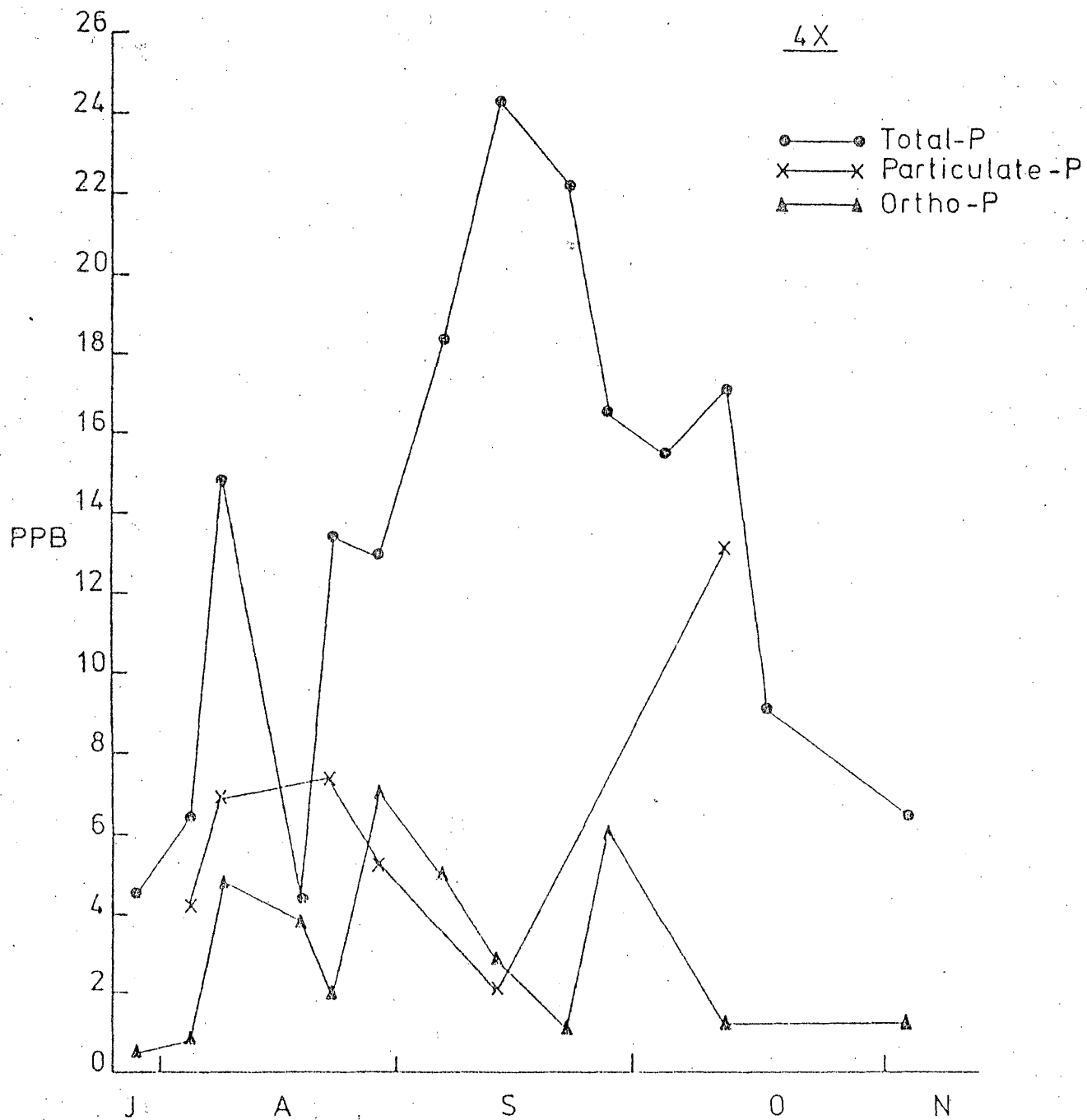


Figure 13. Total phosphorus, particulate phosphorus and ortho phosphorus concentrations in microcosm 4X between July and November 1978.

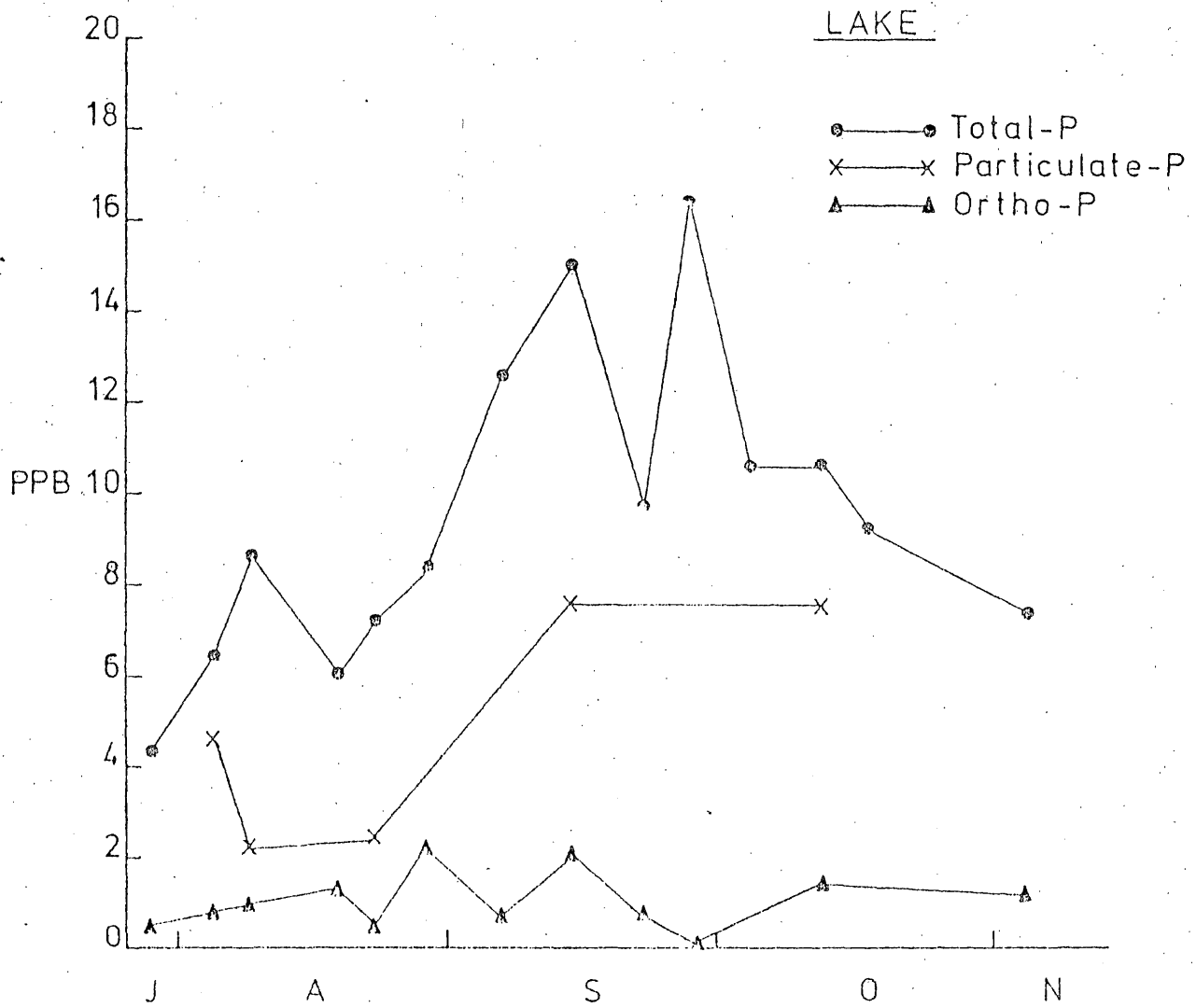


Figure 14. Total phosphorus, particulate phosphorus and ortho phosphorus concentrations in Big Brooklyn Lake between July and November 1978.

Nitrate-Nitrogen

Data on Nitrate-N is presented in Appendix I and illustrated in Figure 15. In the statistical computations the first three dates were omitted because we did not obtain consistent readings with the Beckman DU spectrophotometer. Again, one-tailed paired t-tests were used to determine whether there were differences in nitrate concentrations between treatments. Nitrate in microcosm 8X+N and 4X+N was significantly greater than nitrate in all other microcosm ($\alpha = 0.005$) and the lake ($\alpha = .01$). Nitrate in microcosm 2X+N was significantly greater than 2X and the lake ($\alpha = .15$ and $\alpha = .1$ respectively).

Ammonia-Nitrogen

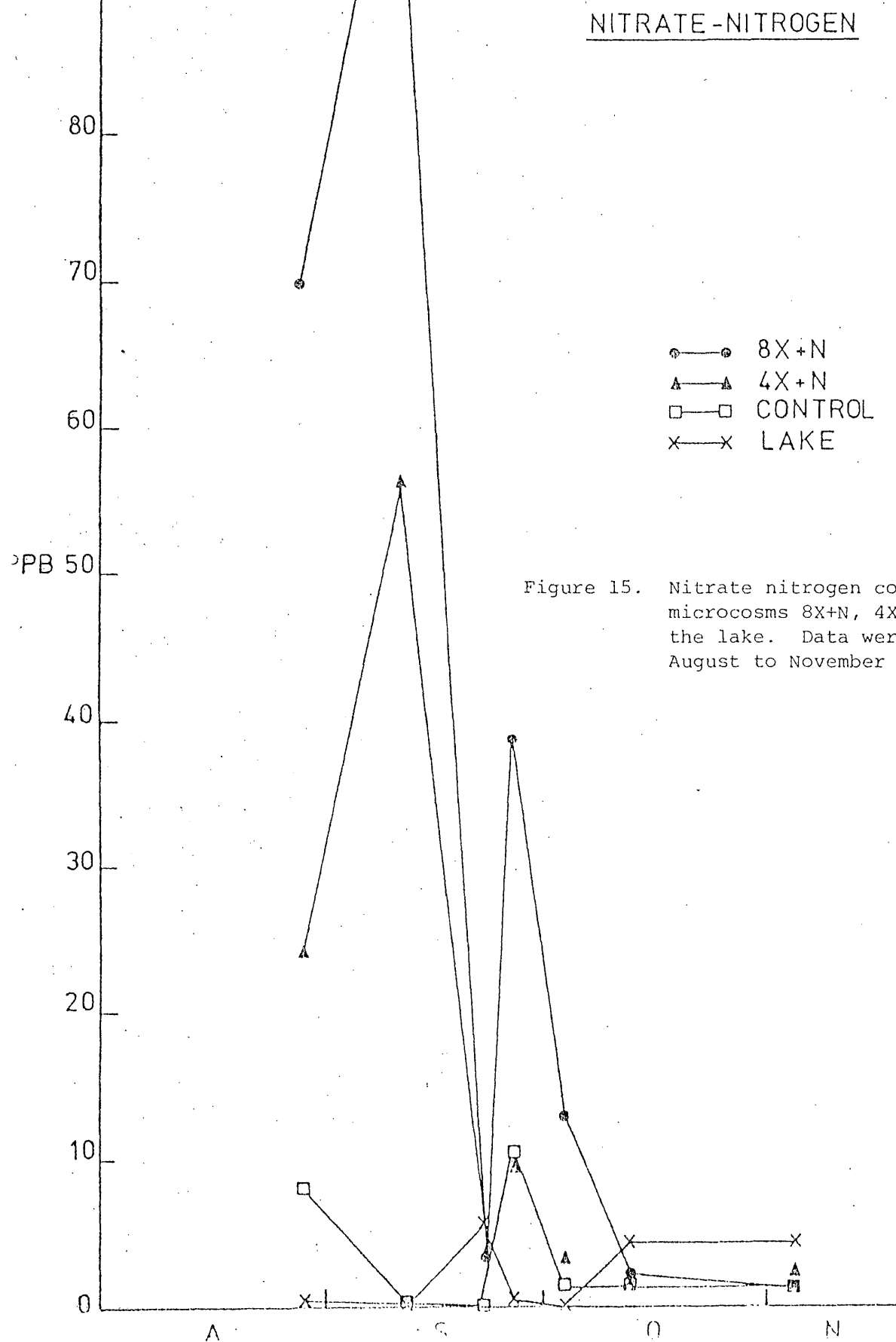
The values obtained for ammonia-N are presented in Appendix J. Because ammonia was not added to the microcosm and we did not have an expected direction of change in concentration, two tailed paired t-tests were used for statistical comparisons. Microcosm 8X+N had significantly less ammonia than the lake ($\alpha = .10$) and the control ($\alpha = .5$). Other comparisons showed microcosm 2X+N to have more ammonia than 8X+N ($\alpha = .20$) but less ammonia than the control or the lake ($\alpha = .2$).

Nitrite-Nitrogen

Nitrite-nitrogen was undetectable at all times.

Chlorophyll a

We measured chlorophyll a as an index of phytoplankton standing crop (see Figure 16 and Appendix K for results). Microcosm 8X+N had significantly more chlorophyll a than all other microcosms except 2X+N ($\alpha = .4$ for the control and 4X, $\alpha = .15$ for the lake and 4X+N, $\alpha = .2$ for 2X). These results indicate that the chlorophyll a concentration tended to be greater in the 8X+N microcosm, but not unequivocally so.



CHLOROPHYLL a

- — ■ 8X+N
- — ○ 4X+N
- ▲ — ▲ 2X
- x — x CONTROL
- — ● 2X+N
- — □ 4X
- △ — △ LAKE

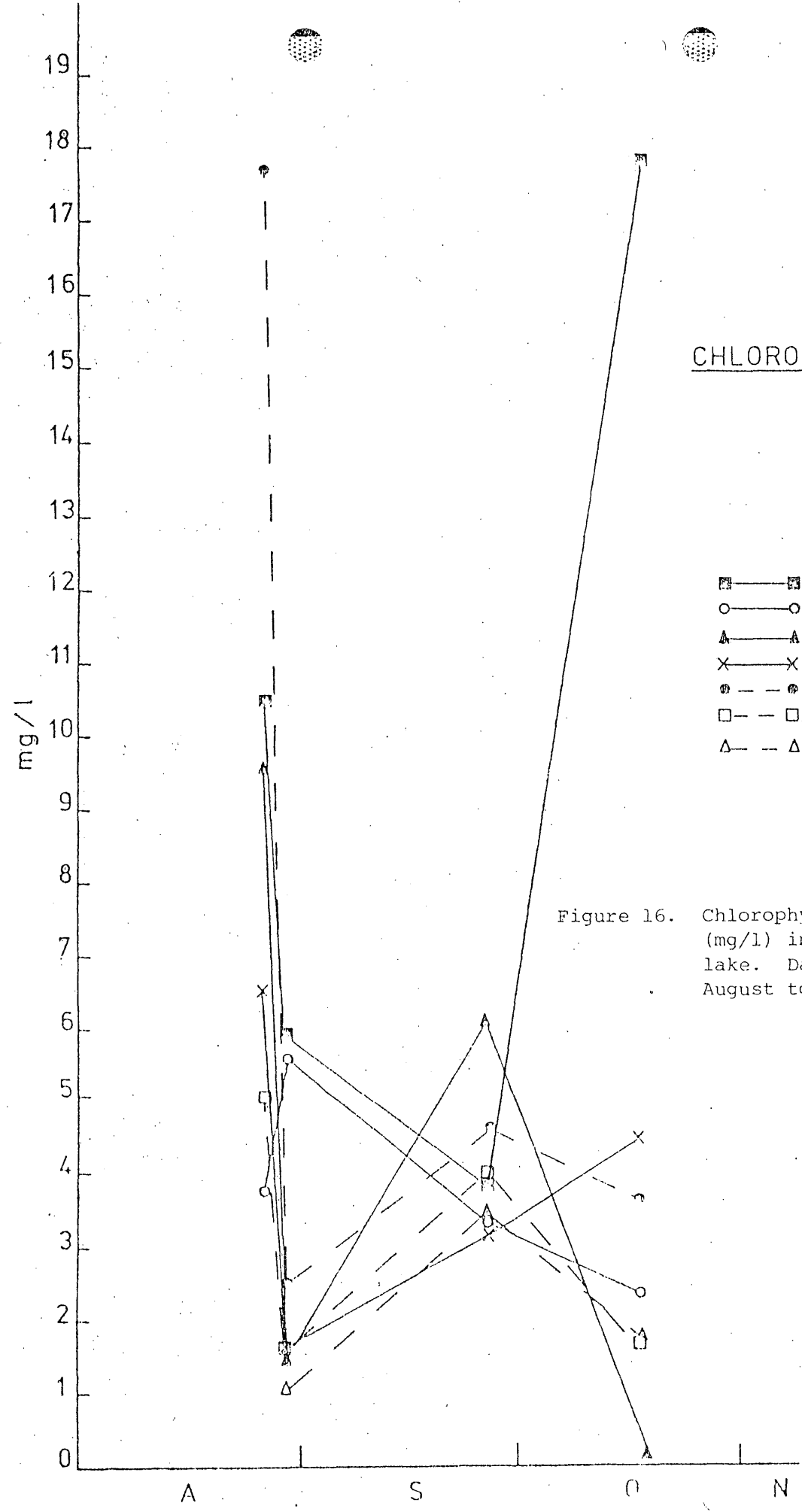


Figure 16. Chlorophyll a concentrations (mg/l) in the microcosms and the lake. Data were collected from August to October 1978.

Although the chlorophyll a concentrations in microcosms 4X+N and 4X were not significantly different from the other microcosms, the trend in these microcosms was the same as microcosm 8X+N (i.e., more particulate phosphorus in the microcosms with greater loading). However, both microcosms 4X and 4X+N had significantly more chlorophyll than the lake ($\alpha = .2$). Microcosm 2X+N also had more chlorophyll a than the lake ($\alpha = .025$).

Between 26 August and 29 August all chlorophyll a concentrations decreased except for 4X+N (Figure 16). Between 29 August and 26 September chlorophyll a in 8X+N and 4X+N decreased, but increased in the other microcosms. By 18 October chlorophyll a in 8X+N and the lake increased, but chlorophyll a in all the other microcosms and the lake decreased.

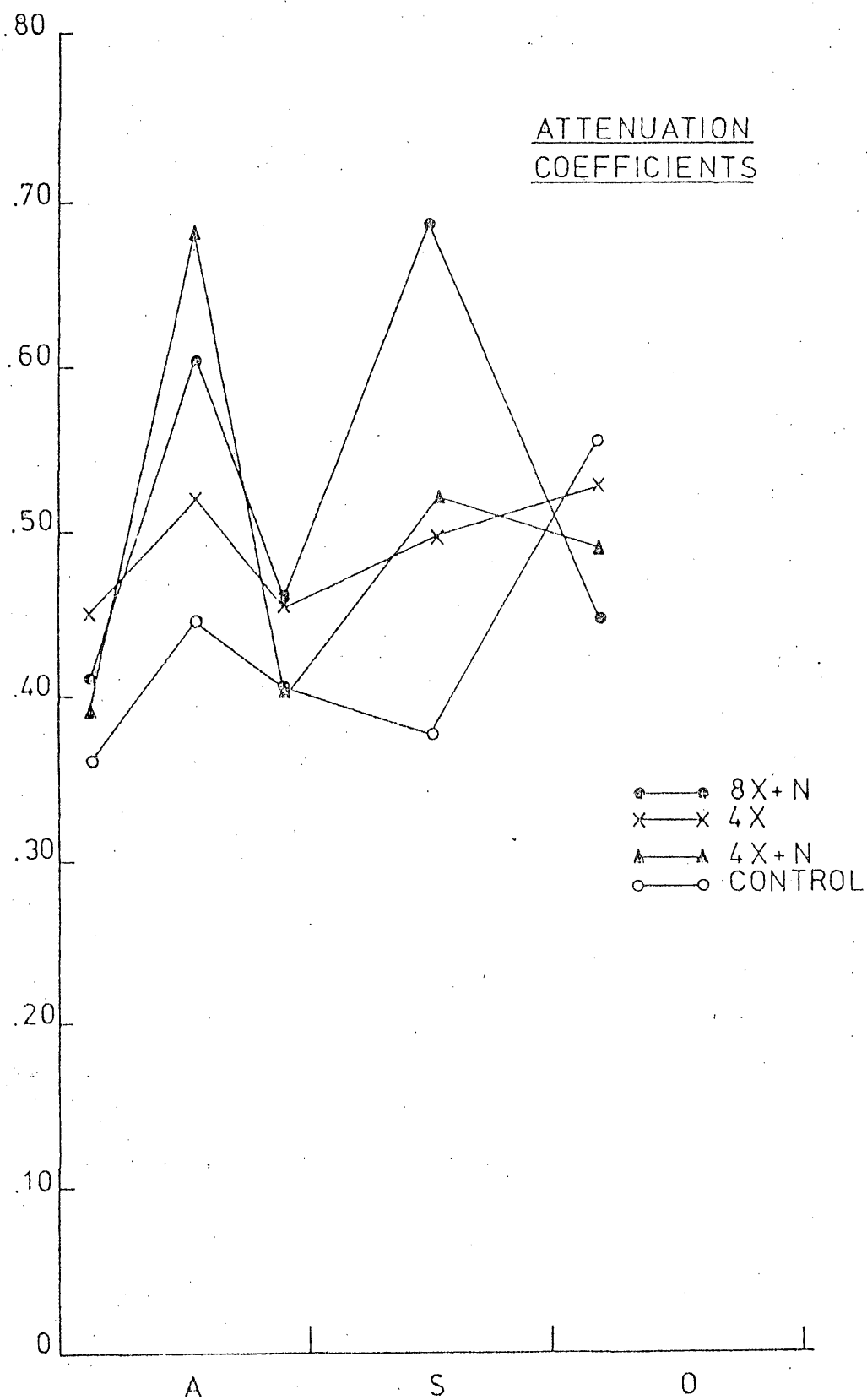
Attenuation Coefficients

A general trend is discernible in data on the attenuation coefficients; larger loadings were associated with greater attenuation coefficients (Figure 17 and Appendix I). Microcosm 4X+N had significantly greater attenuation coefficients than microcosm 2X and the control ($\alpha = .15$). Although the differences between 8X+N and 4X+N were not significant there was a trend that suggests 8X+N was slightly more turbid than 4X+N. Attenuation coefficients in microcosm 4X were greater than attenuation coefficients in microcosms 2X and the control ($\alpha = .05$). None of the microcosms receiving the greater loads had attenuation coefficients which were significantly different from those in 2X+N or from each other.

Cyclops bicuspidatus thomasi

Figure 18 illustrates the results from enumeration of Cyclops bicuspidatus thomasi. There were two peaks in standing crop; a major one in August and a minor one in late September and October. The only significant difference in standing crops occurred between microcosm 2X+N and

Figure 17. Attenuation coefficients for microcosms 8X+N, 4X, 4X+N and the control. The ordinate has units of m^{-1} . Data were collected from August to October 1978.



the lake ($\alpha = .2$), with the lake having the largest numbers of cyclops.

Appendix M presents the enumeration data on copepods and eggs. The latter data have not yet been analyzed.

Daphnia pulex

Several significant differences in the population sizes of Daphnia pulex were observed when comparing treatments (Table 4).

Except for microcosm 4X and 8X+N, the populations of Daphnia pulex reached their maximum size about the first of September (Figure 19, Appendix N). Microcosm 8X+N may have had a low but sustained peak from the middle of August to the first of September (Figure 17). Microcosm 4X showed a distinct peak toward the end of August. The trend in the data is that microcosms 4X and 4X+N had more animals than the microcosms with lower nutrient loads, except for microcosm 2X+N and the lake.

Chydorinae

Chydorinae (species unknown at present) populations peaked toward the end of September through October (Figure 20). Comparing Figure 20 to Figure 19 one can see that the Chydorinae peaked after the Daphnia pulex started to decline. The only significant difference in population size occurred between both microcosm 4X and the control (larger populations) and the lake (smaller populations; $\alpha = 0.2$). Appendix O presents the tabulated data for Chydorinae.

Polyarthra

The population size of Polyarthra was low when sampling began, then decreased further in August, but finally increased toward the end of September (Figure 21). The increase continued in all microcosms and the lake, except for microcosm 4X+N, until the experiment was terminated. The population in microcosm 4X was significantly larger than those in 8X+N ($\alpha = .1$) and in the lake ($\alpha = .2$). However, the population in 4X started

Table 4. Significant differences in the population sizes of Daphnia pulex between the microcosms and between the microcosms and the lake.

		Treatments with larger numbers of <u>Daphnia pulex</u>						
		Lake	Control	2X	2X+N	4X	4X+N	8X+N
Treatments with smaller numbers of <u>Daphnia</u> <u>pulex</u>	Lake	$\alpha=.2$						
	Control				$\alpha=.1$	$\alpha=.2$	$\alpha=.2$	
	2X				$\alpha=.1$	$\alpha=.2$	$\alpha=.1$	
	2X+N						$\alpha=.1$	
	4X	$\alpha=.1$						
	4X+N	$\alpha=.2$						
	8X+N	$\alpha=.1$			$\alpha=.1$	$\alpha=.2$	$\alpha=.2$	

41
CYCLOPS BICUSPIDATUS THOMASI

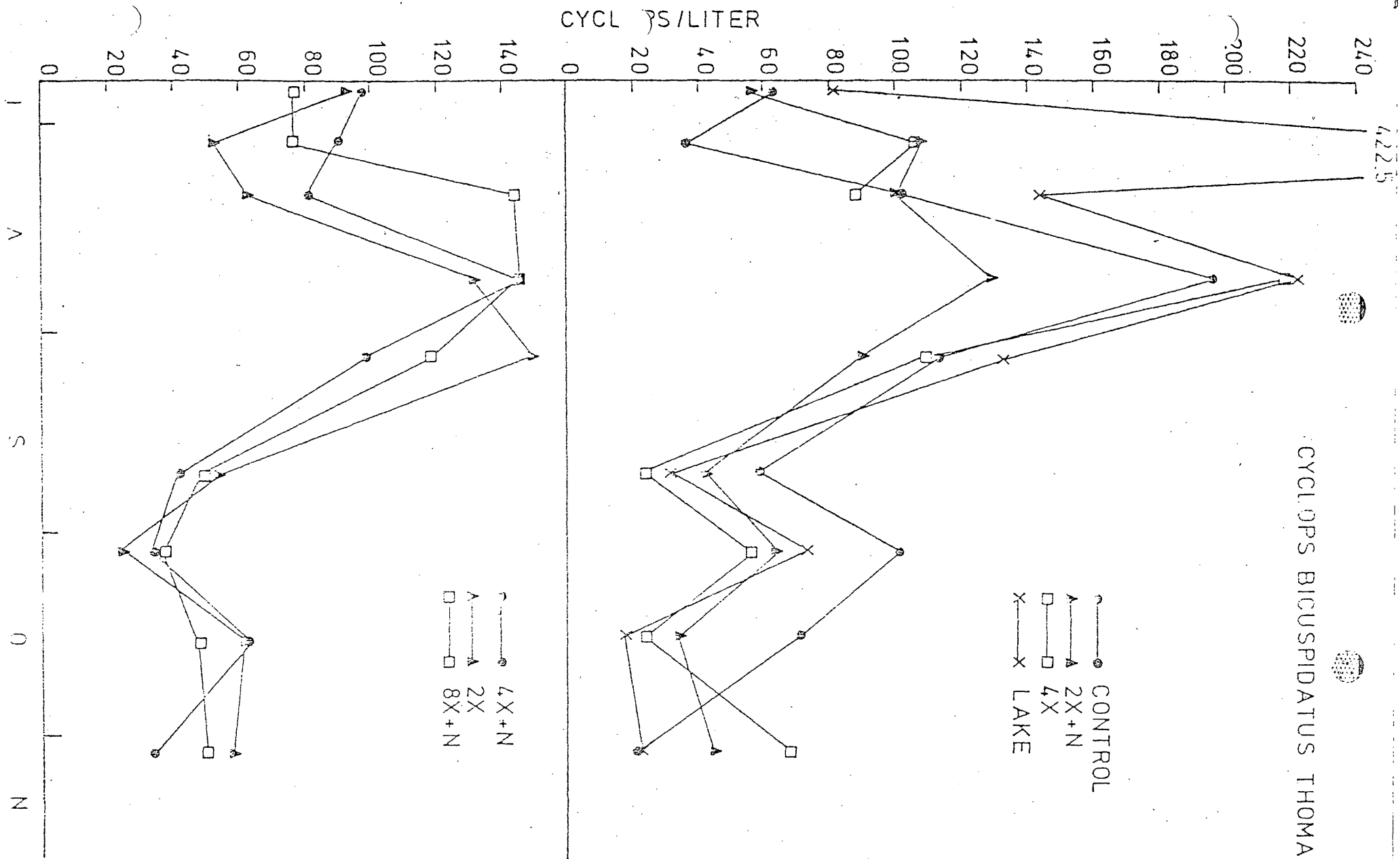


Figure 18. Total number of *Cyclops bicuspidatus thomasi* per liter in the microcosms and the lake. Data were collected from July to November 1978.

DAPHNIA PULEX

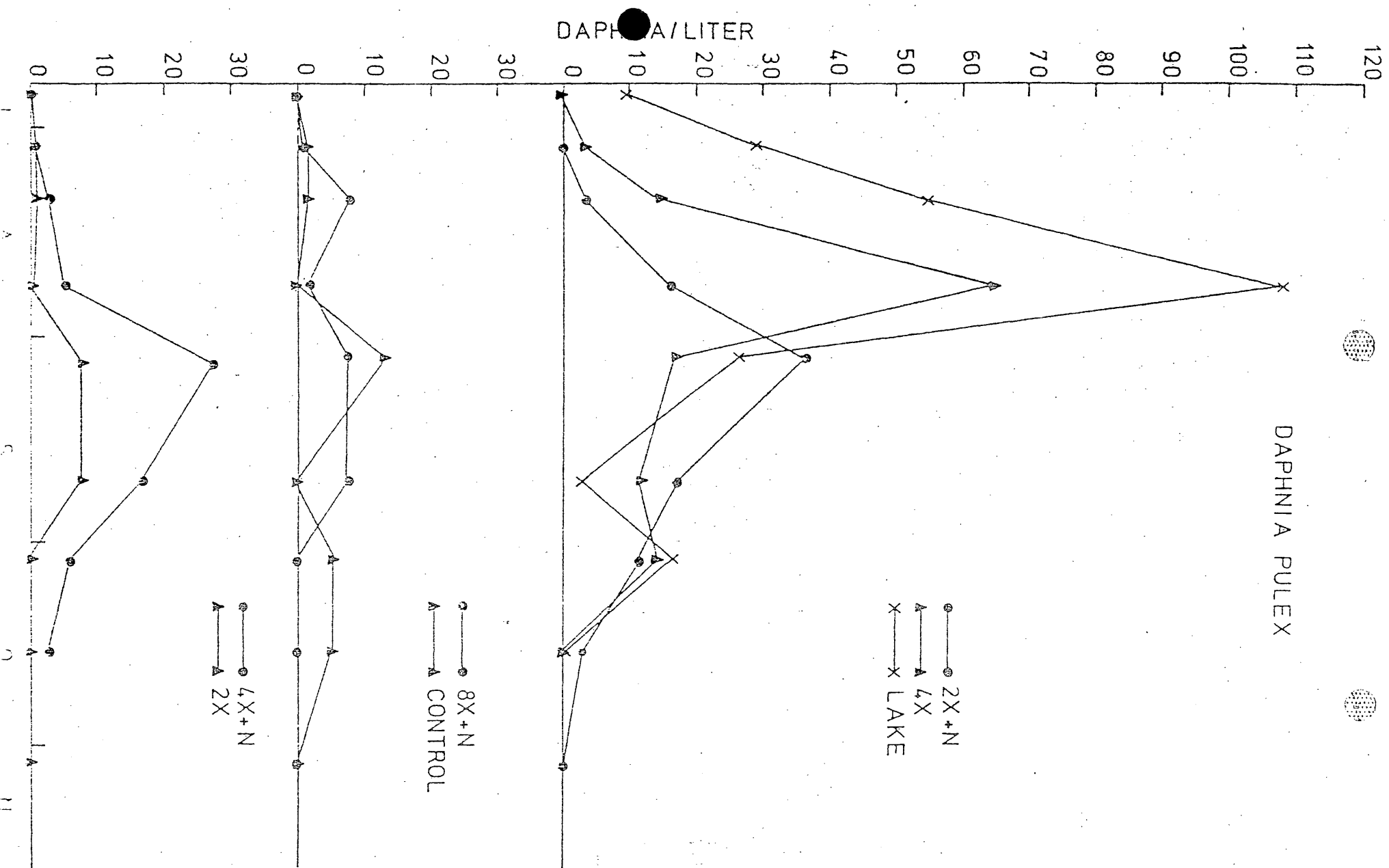


Figure 19. Total numbers of *Daphnia pulex* per liter in the microcosms and the lake. Data were collected from July to November 1978.

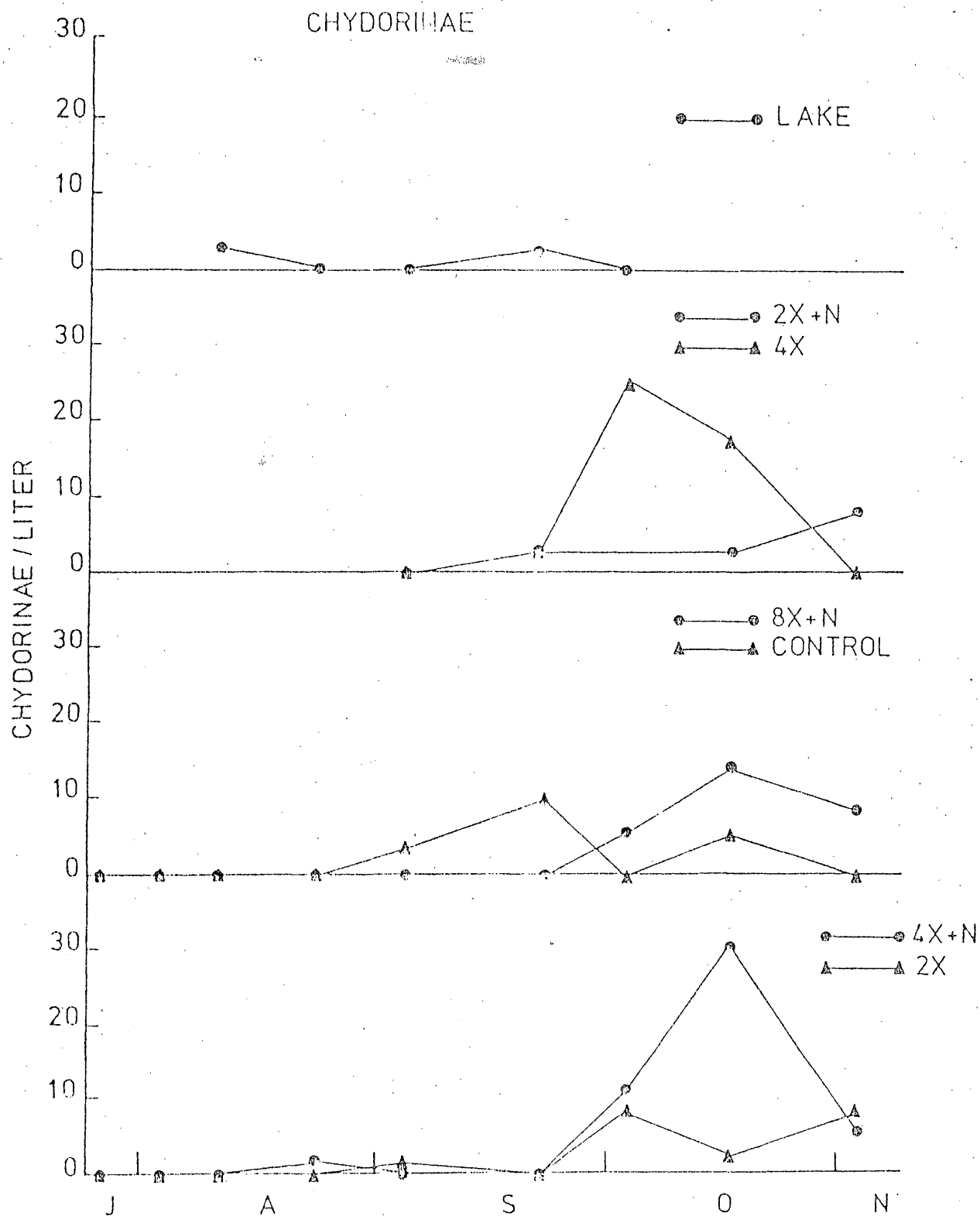


Figure 20. Total numbers of Chydorinae per liter in the microcosms and the lake. Data were collected from July to November 1978.

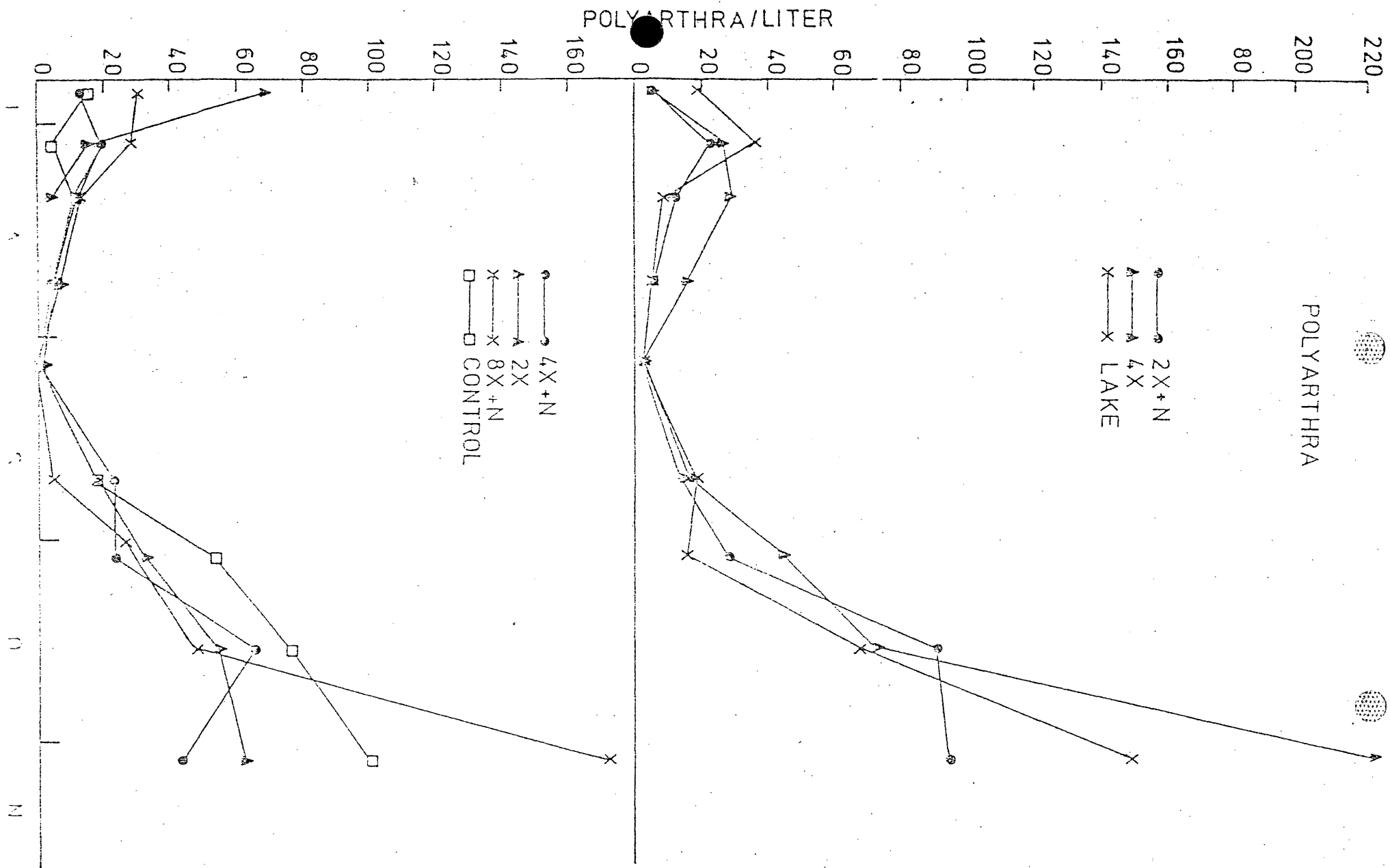


Figure 21. Total numbers of the rotifer Polyarthra per liter in the microcosms and the lake. Data were collected from July to November 1978.

to increase before the other two, which probably accounts for the significant differences. Appendix P presents the data on population sizes of Polyarthra in tabular form.

Keratella cochlearis

Except for the lake and the microcosm 4X, populations of K. cochlearis appear to have peaked prior to those of Polyarthra (compare Figures 22 and 21), and then to have decreased when Polyarthra started to increase. The population of K. cochlearis in microcosm 8X+N was significantly greater than that in the lake ($\alpha = .05$) and that in microcosm 4X+N ($\alpha = .2$). The control microcosm's population was significantly larger from that of the lake ($\alpha = .05$) and from that in microcosm 4X+N ($\alpha = .2$). Microcosm 4X had more animals than 4X+N ($\alpha = .2$). See Appendix Q for data of the population sizes of K. cochlearis.

Keratella quadrata

Appendix R presents the data on Keratella quadrata population sizes. Because of the few data points a figure was not drawn. In addition, the population sizes of K. quadrata were not significantly different between microcosms or between microcosms and the lake.

Kellicottia longspina

Figure 23 shows the distribution of K. longspina over time and Appendix 5 gives the tabulated results. K. longspina populations in microcosm 2X+N were significantly ($\alpha = .2$) greater than the lake, microcosm 4X, microcosm 4X+N and the control. Except for microcosm 4X+N and the control, K. longspina populations in all microcosms and the lake were significantly greater than those in microcosm 8X+N (microcosms 2X and 2X+N, $\alpha = .1$). It appears that the microcosms receiving lesser loadings contain more K. longspina than those receiving higher loadings.

KERATELLA COCHLEARIS

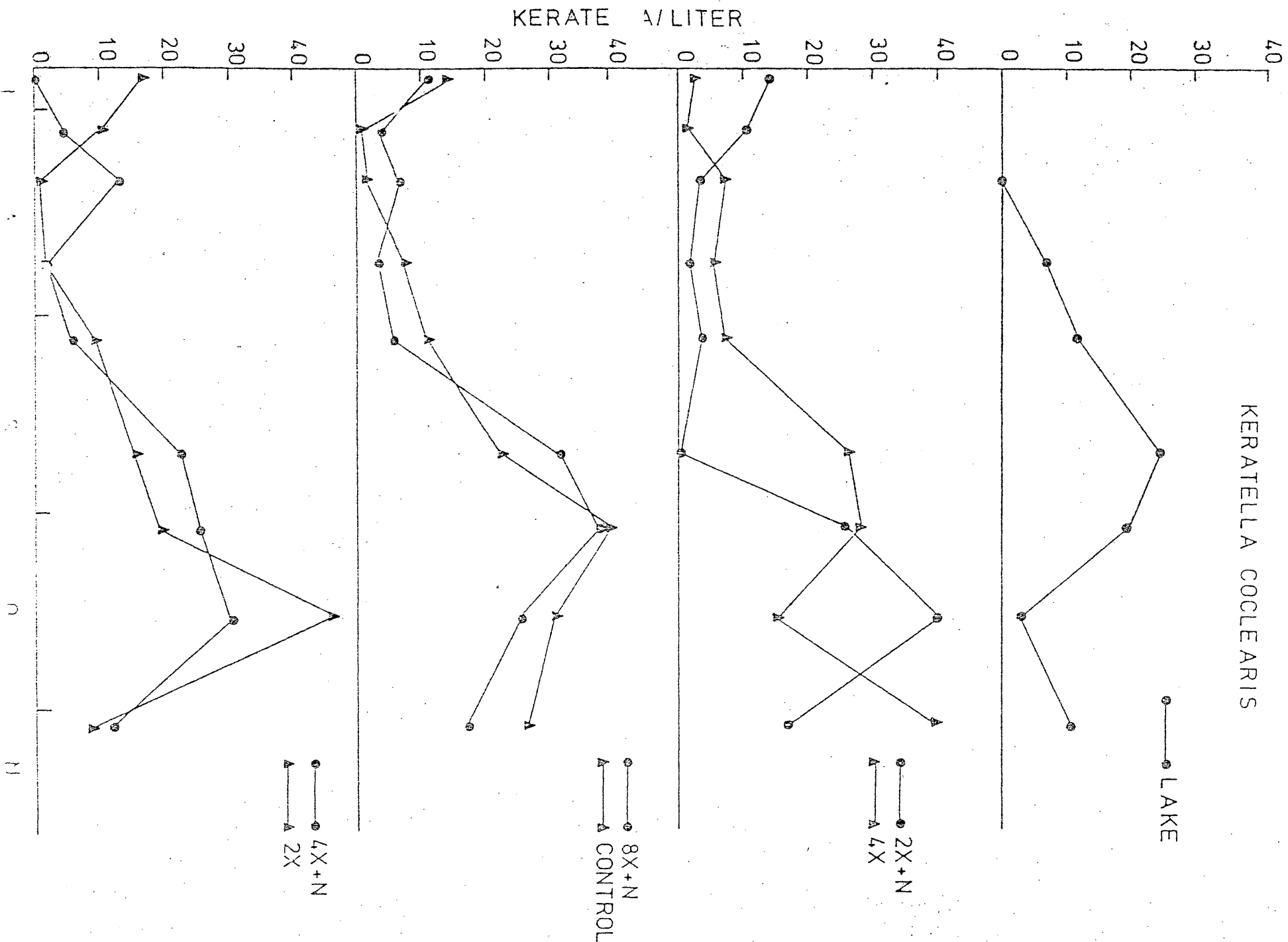


Figure 22. Total numbers of *Keratella cochlearis* per liter per microcosm and the lake. Data were collected from July to November 1978.

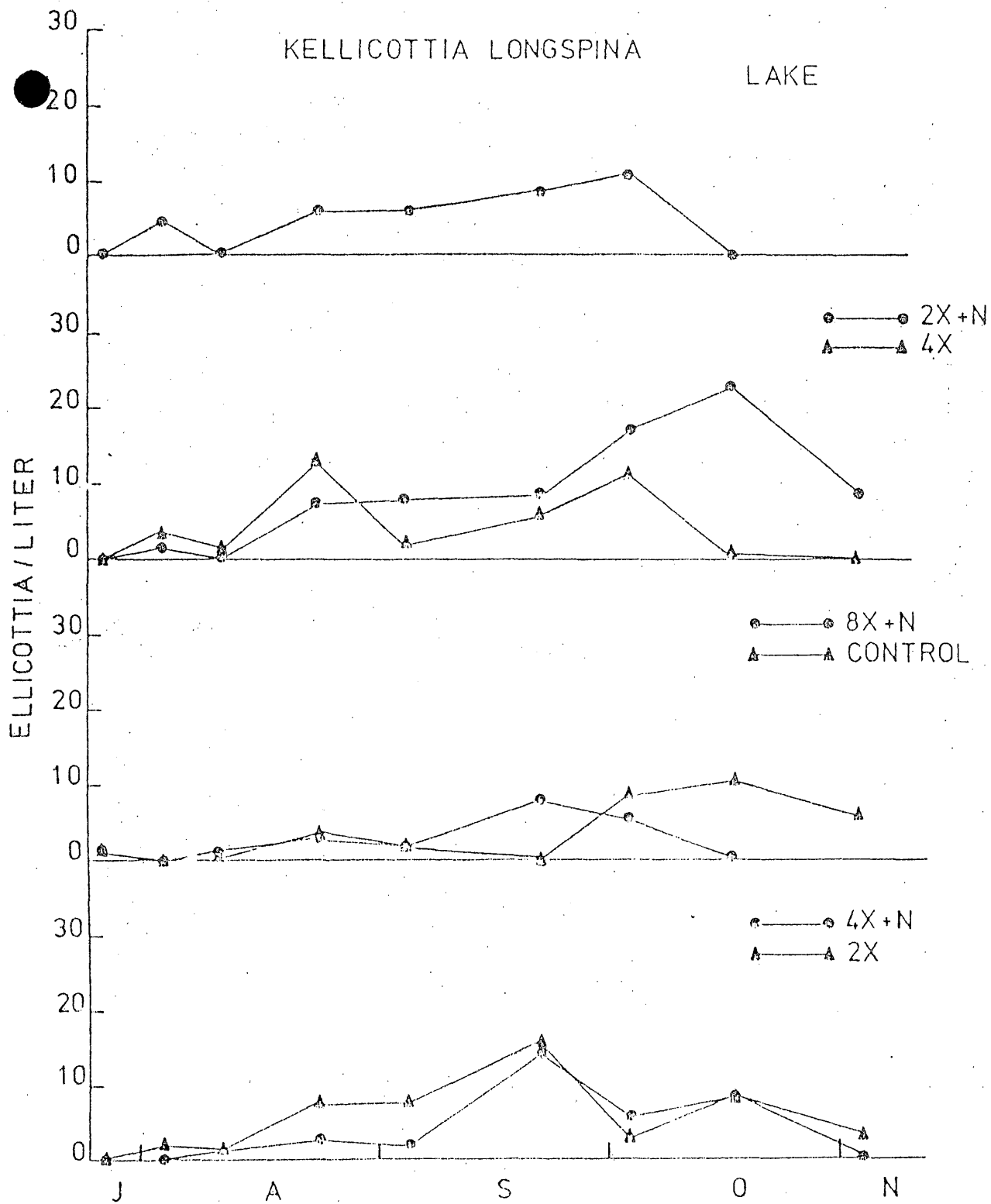


Figure 23. Total population size of *Kellicottia longspina* in numbers per liter for the microcosms and the lake. Data were collected from July to November 1978.

Other Rotifers

This category consists of a variety of other rotifer species which were not identified. They occurred in very small numbers and therefore were not dominant organisms. Appendix T presents the tabulated data on their population sizes. Microcosm 4X+N had a significantly greater population than microcosm 2X+N ($\alpha = .02$) and the lake ($\alpha = .2$). Also, microcosm 2X and the control had a significantly larger population size than microcosm 2X+N ($\alpha = .2$ level).

Total Rotifers

The data on population sizes of all rotifer taxa were combined to see if a general trend could be observed for all Rotifera. The plotted data (Figure 24) looks much like that for the Polyarthra data (Figure 21). There were no significant differences between population sizes between microcosms and between the microcosms and the lake revealed through the paired t-tests. Appendix U presents the tabulated data.

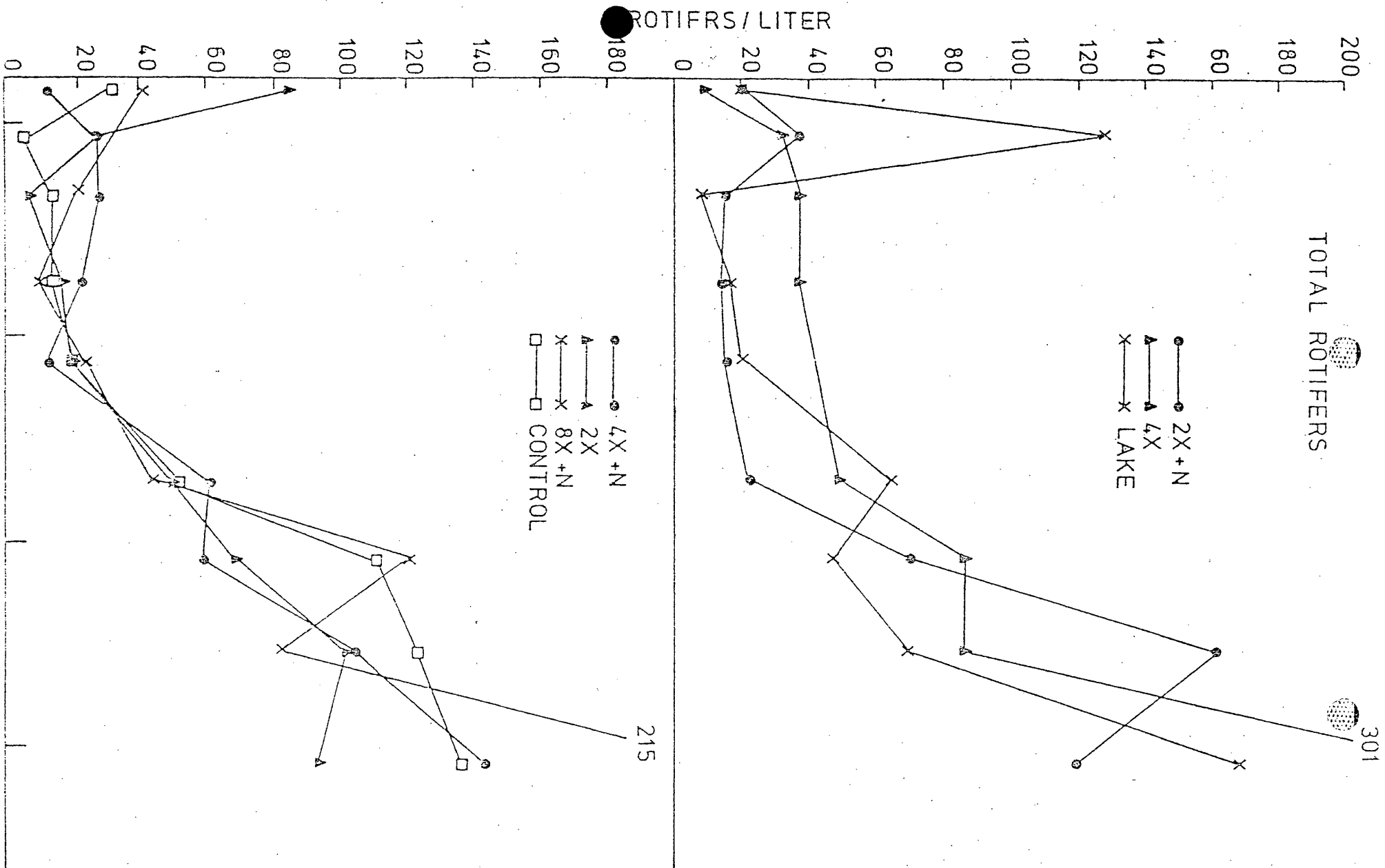


Figure 24. Total population size for the total rotifer population in numbers per liter in the microcosm and the lake. Data were collected from July to November 1978.

DISCUSSION

As background to our use of microcosms, a brief description of the theoretical aspects is in order. There are a variety of different microcosms useful for a variety of studies. Giddings (1978) lists the different types and classifies them under two major divisions, ecosystem models and food chain models. With ecosystem models one can study material cycling, energy flow and stability. Food chain models can be used for studies of population dynamics, predator-prey interactions and trophic dynamics. Our microcosm probably best falls into the food chain category because we have or will have information on population dynamics of zooplankton (e.g., total population counts, counts of the various developmental stages, clutch size, birth rates and death rates) as a result of nutrient additions.

Leffler (1978) believes that microcosms should be used for "general" rather than "specific" investigations. His reasoning is based on the fact that microcosms cannot perfectly mimic the real world and therefore cannot be used to exactly model a "specific" ecosystem. But microcosms will reveal "general" trends which do occur in the real world. For example, we were using microcosms as small lakes within a lake to understand the effects of nutrient loading in the limnetic region of the lake. However, we could not control the growth of periphyton on the substrate provided by the microcosms' walls. Therefore, we have to consider the resultant periphyton in terms of their utilization of added nutrients. And since periphyton is not an important component in the limnetic zone of the lake, the microcosms are not perfect copies of the limnetic ecosystem.

Leffler (1978) also pointed out common problems associated with the use of microcosms: time scales; lack of replication; parameter measurement; environmental control; historical control and, economic feasibility. As an example of time scale problems consider the following. Ecosystem structure at a particular time is the result of many factors (e.g., temperature, nutrient input variation, seasonal differences). Many microcosms do not mimic seasonal changes occurring in the ecosystem because of problems such as the physical maintenance of the microcosms. For example we were able to use microcosms only during the periods the lake was free of ice although the effects of nutrient addition are not limited to the open water period.

Replication can become a problem because of the additional man hours required to maintain and collect data. Also it is not uncommon for two replicates to behave quite differently. A possible explanation for microcosms being different is that the initial species composition was different resulting in different population interactions. Therefore, more than two replicates could well be necessary. A parameter measurement problem is illustrated by our experiment. We were interested in the distribution of phosphorus in the limnetic region of the lake. Because of the growth of periphyton on the walls of the microcosms we also have to consider the phosphorus component in the periphyton. Although not an insurmountable problem, it does complicate the measurements of phosphorus in the various fractions.

Environmental control is a much greater problem in the field than in the laboratory. Our in-situ microcosms varied as the natural environment varied. Therefore the complexities introduced in the study by environmental

changes must be taken into account. In the laboratory investigators control the environment which allow the complexities in the natural system to be ignored. However, the experiment is not reflecting natural conditions but a subset thereof.

Historical control can result in problems in interpretation. Assume, for example, a species of zooplankton is dominant in a microcosm that does not contain the top carnivore (i.e., fish). An interpretation of results might be that nutrient enrichment increased zooplankton population abundance and/or species richness where in fact it was the absence of the top carnivore that caused the observed increase.

Economic feasibility is always a problem when monies are limiting. A problem we had was deciding whether the number of tubes we built with our resources should be used to maximize information or to replicate the experiments minimizing information. We chose to maximize information, sacrificing replication.

In general, microcosms can provide a wealth of information and will become a more integral part of ecosystem investigations, especially in community studies.

Nutrient Additions, Algal and Zooplankton Standing Crops

There were indications that the addition of phosphorus and nitrogen did increase the standing crop of algae in Big Brooklyn Lake. For example more dissolved oxygen occurred in microcosm 8X+N and there was less dissolved carbon dioxide. Both results indicate increased photosynthesis. Also, the data on chlorophyll a and attenuation coefficients suggest increased loading caused increased standing crops. Chlorophyll a values in microcosm 2X+N were greater than microcosm 2X ($\alpha = .2$), and although

not significant microcosm 4X+N had the same trend (i.e., greater chlorophyll a values) compared to microcosm 4X. This suggests that the addition of nitrate plus phosphorus enhanced standing crops better than the addition of phosphorus alone. If we assume that particulate phosphorus is an index of phosphorus incorporated in algae, then the standing crop of algae was greater in microcosm 8X+N than the other microcosms. We found a positive correlation between particulate phosphorus and total phosphorus when the data from all the microcosms and the lake were pooled (Figure 25). As the total phosphorus concentration increase so did the particulate phosphorus concentration. This implies that with increased loading the standing crop increased. However, a more definitive answer to whether algal standing crops increased more in the microcosms receiving greater loads will be available only when the algal counts are made.

As was noted previously there were some significant differences in the population sizes of the zooplankton. Daphnia pulex had larger populations in microcosms 2X+N, 4X and 4X+N than in microcosms 2X and 8X+N. These results cannot be interpreted without additional data (e.g., reproductive rates, death rates, food availability). Once we have these analyses we will be able to discover how the zooplankton populations respond to loading and hence how loading affects the availability of an important food for fish.

There was a negative correlation between the pooled D. pulex data and the pooled particulate phosphorus data (Figure 26). This suggests that grazing by D. pulex data and the pooled particulate phosphorus data (Figure 26). This suggests that grazing by D. pulex removed and hence decreased the amount of particulate matter in the water. Figure 27 supports this interpretation particularly in microcosms 4X+N and 4X. To

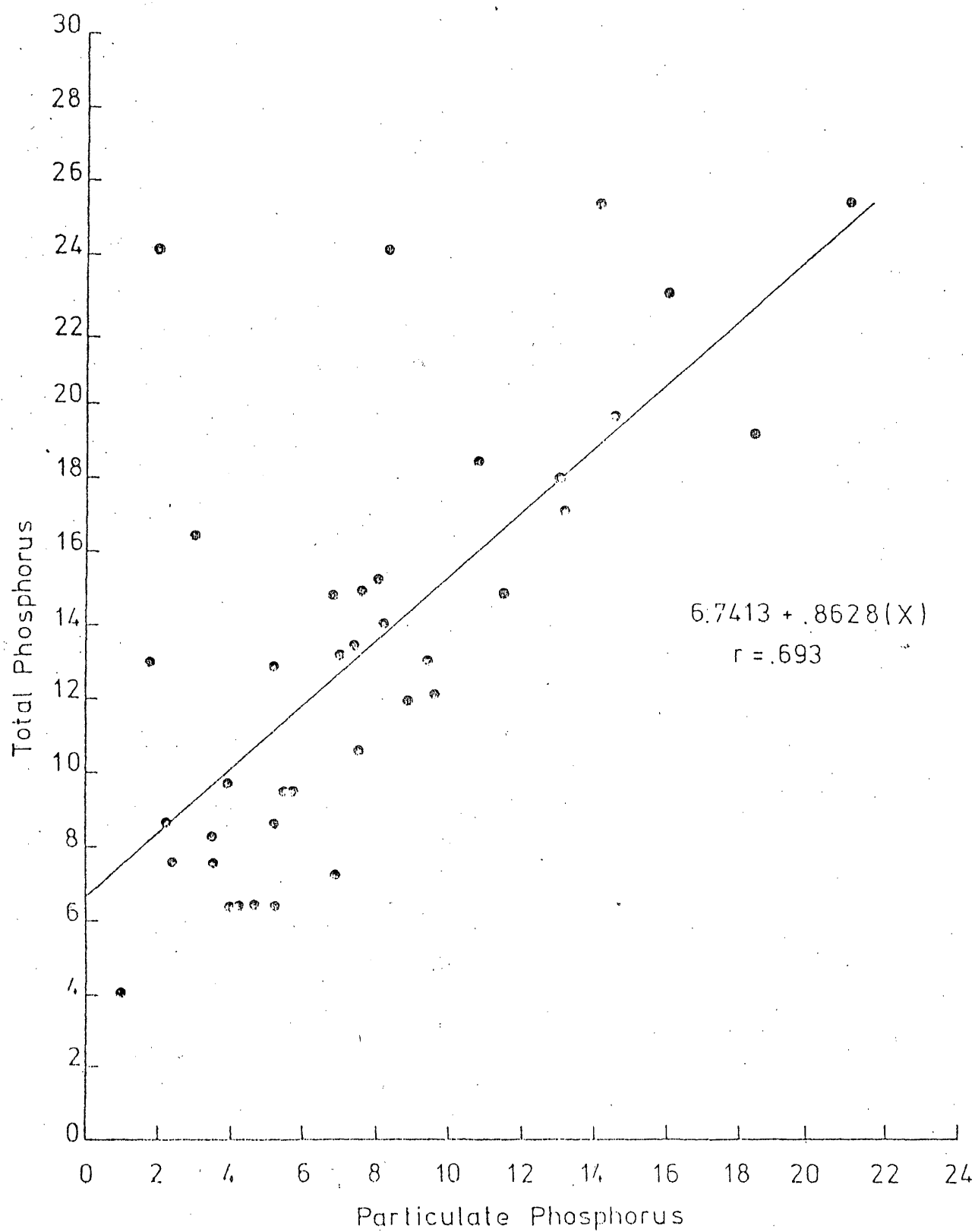


Figure 25. A scatter diagram illustrating the correlation between particulate phosphorus and total phosphorus. Data is in ppb.

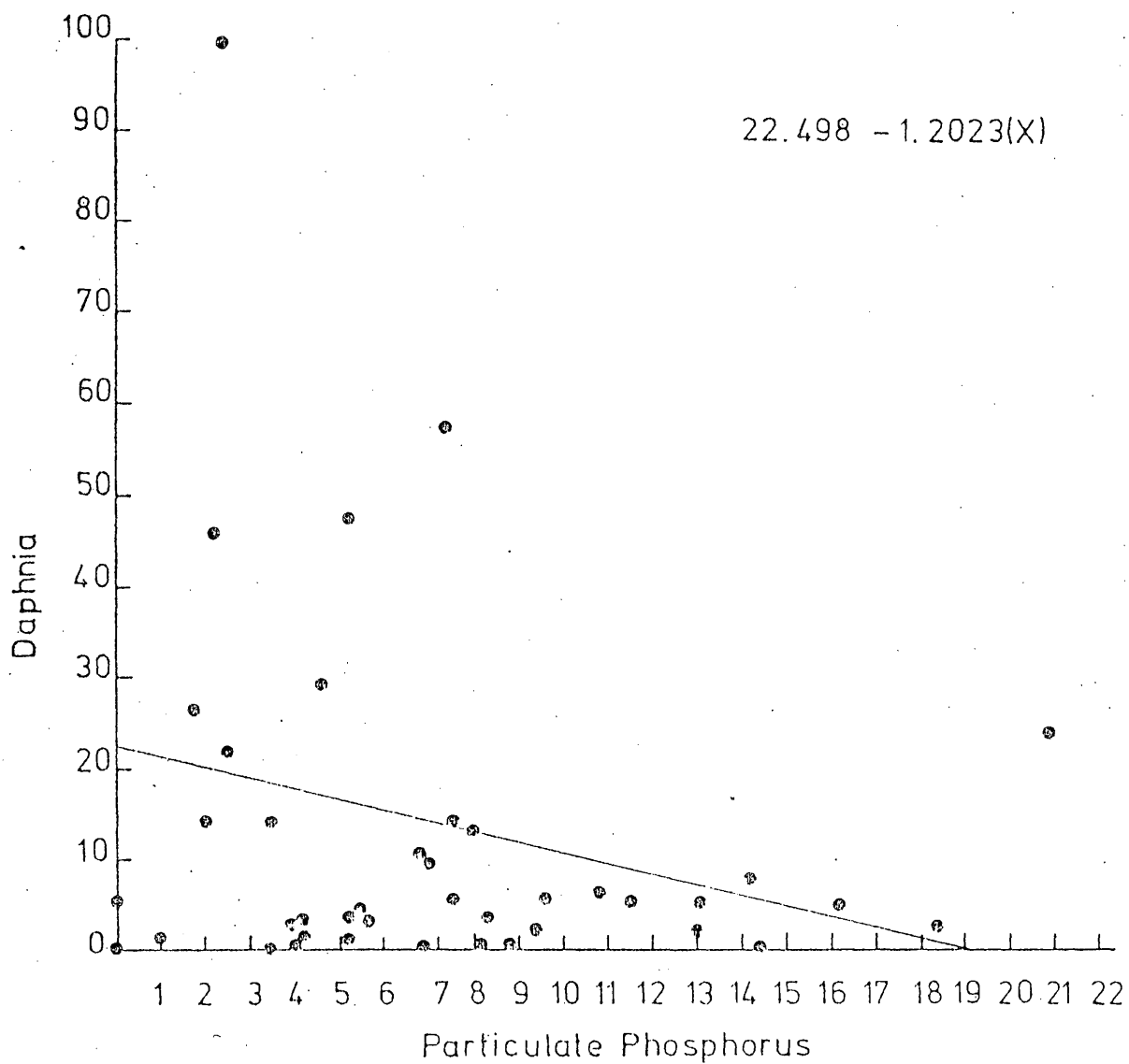
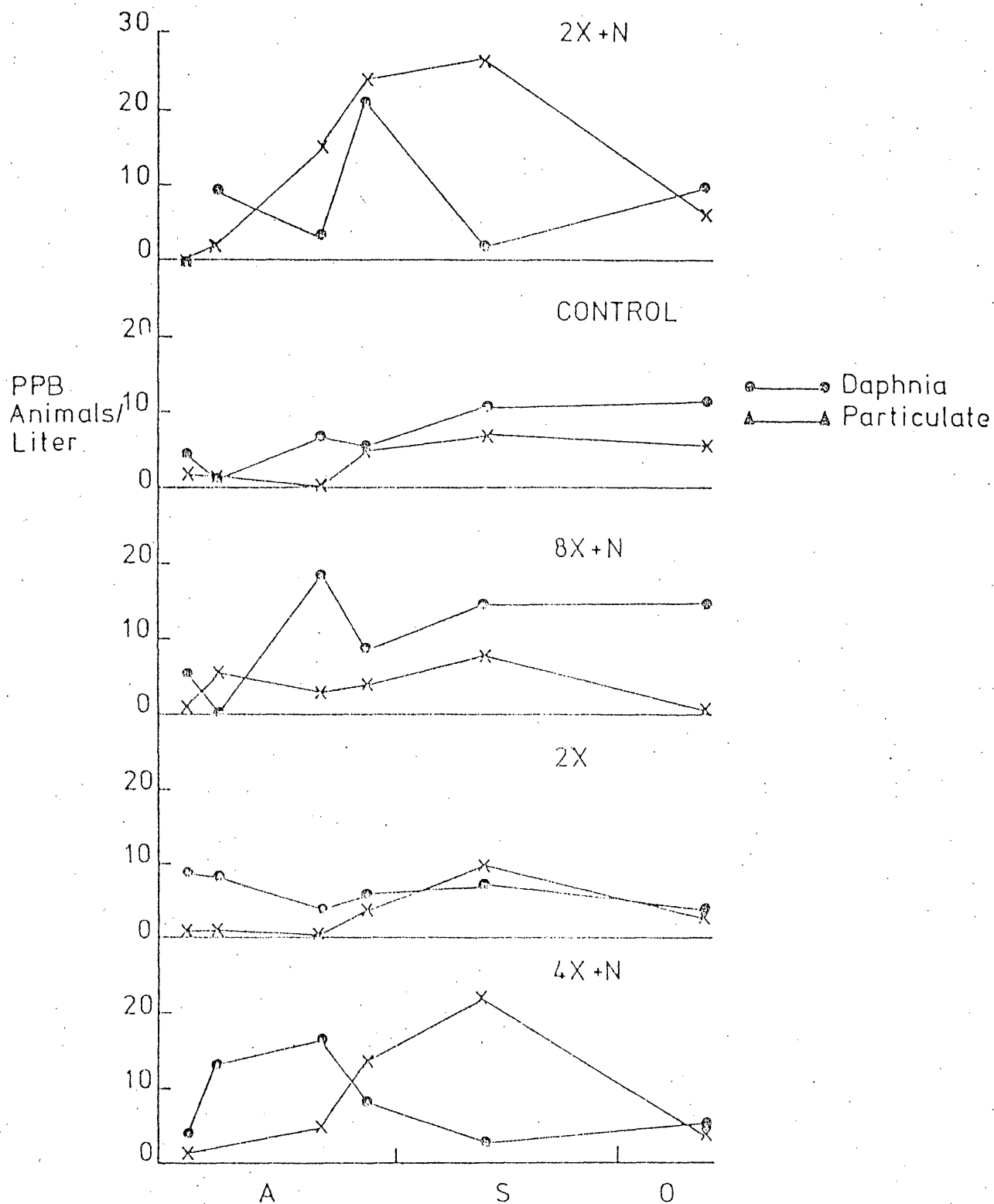


Figure 26. A scatter diagram showing the regression between Daphnia pulex and particulate phosphorus. The data are pooled from the microcosms and the lake.

Figure 27. *Daphnia pulex* population sizes and particulate phosphorus concentrations for the microcosms and the lake. Data are from 1978.



further test this idea we regressed all comparable data on chlorophyll a concentrations and D. pulex population size. The regression was not significant for the pooled data. However, correlation coefficient for several microcosms alone were significant (4X+N, $\alpha \leq .025$; 8X+N, $\alpha \leq .005$ and the control, $\alpha = .05$; see Figure 28). Considering Figure 29 it appears that chlorophyll a generally decreased when the abundance of D. pulex increased, even though the expected trend was statistically significant in only two microcosms.

We found a weak positive correlation (Figure 30) between Cyclops bicuspidatus thomasi and D. pulex. C. bicuspidatus thomasi is a predator on D. pulex and if predation by C. bicuspidatus thomasi was intense we might expect a negative correlation between the population sizes of the two species. However, since the correlation was weak the effects of C. bicuspidatus thomasi on populations of D. pulex are more subtle, and cannot be evaluated until further analyses are complete. It is more likely that the death rate of D. pulex will correlate negatively with C. bicuspidatus thomasi.

Total rotifers were negatively correlated with total phosphorus (Figure 31), not correlated with D. pulex populations, and positively correlated with C. bicuspidatus populations (Figure 32). Since cladocerans in general have higher filtering rates than rotifers and therefore can remove more food items from the water column (Allen, 1978), we felt that high D. pulex populations might depress the rotifer populations. As noted above there was not a correlation. However, there might have been a subtle effect of D. pulex (i.e., reduction of food items by D. pulex, decreased birth rate or increased death rate of rotifers) on rotifers. But this cannot be evaluated until further analyses are completed. The correlation between the C. bicuspidatus thomasi might be because of

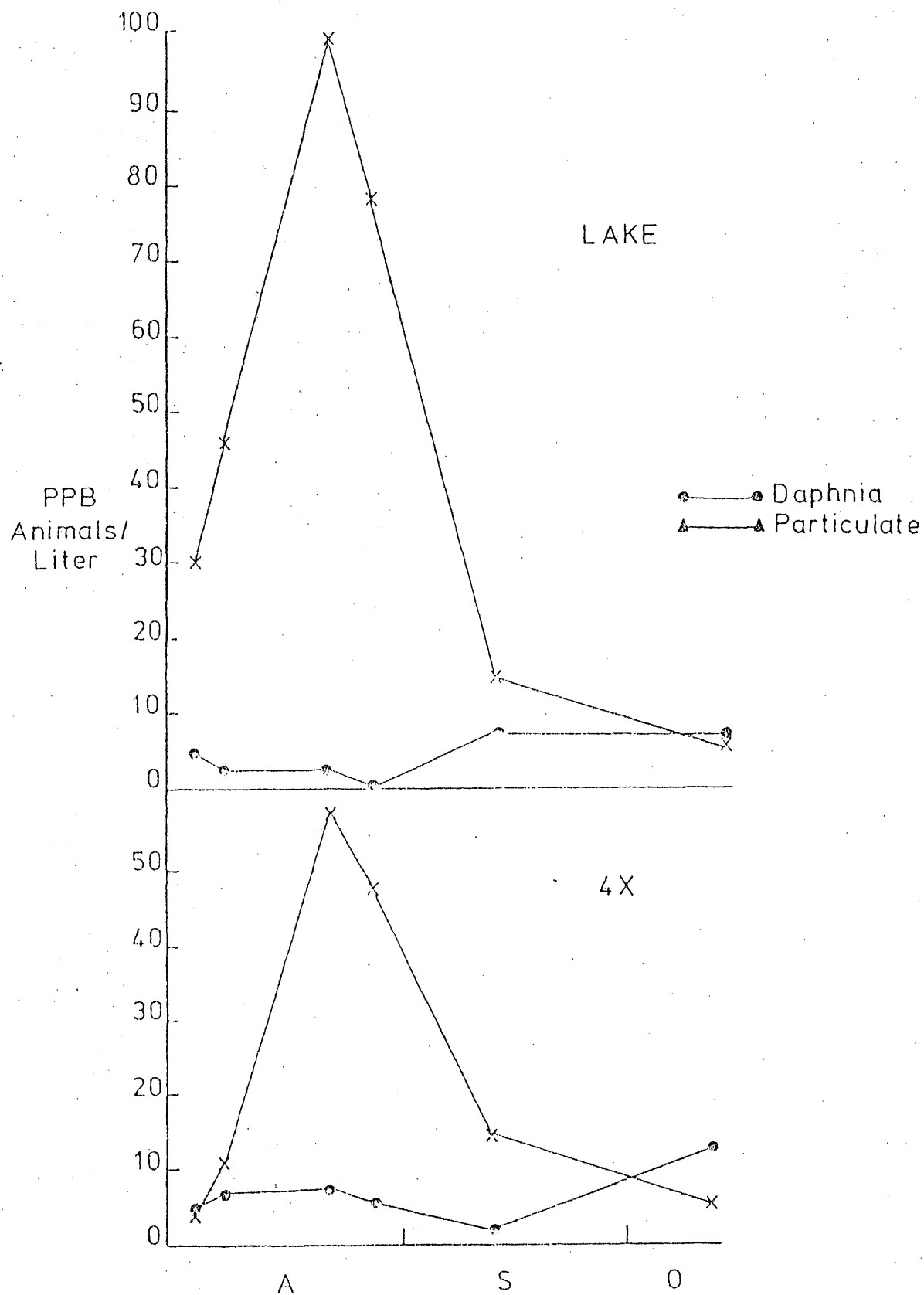


Figure 27. (Continued)

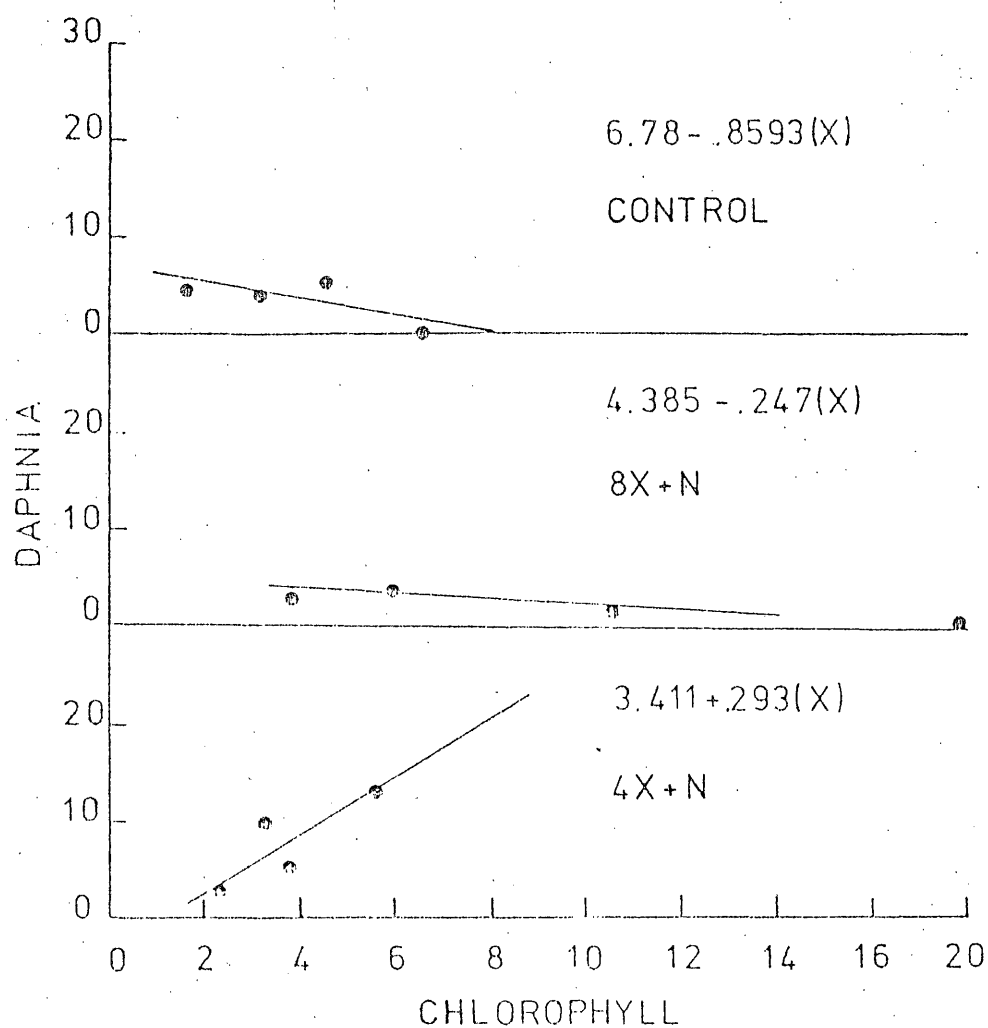
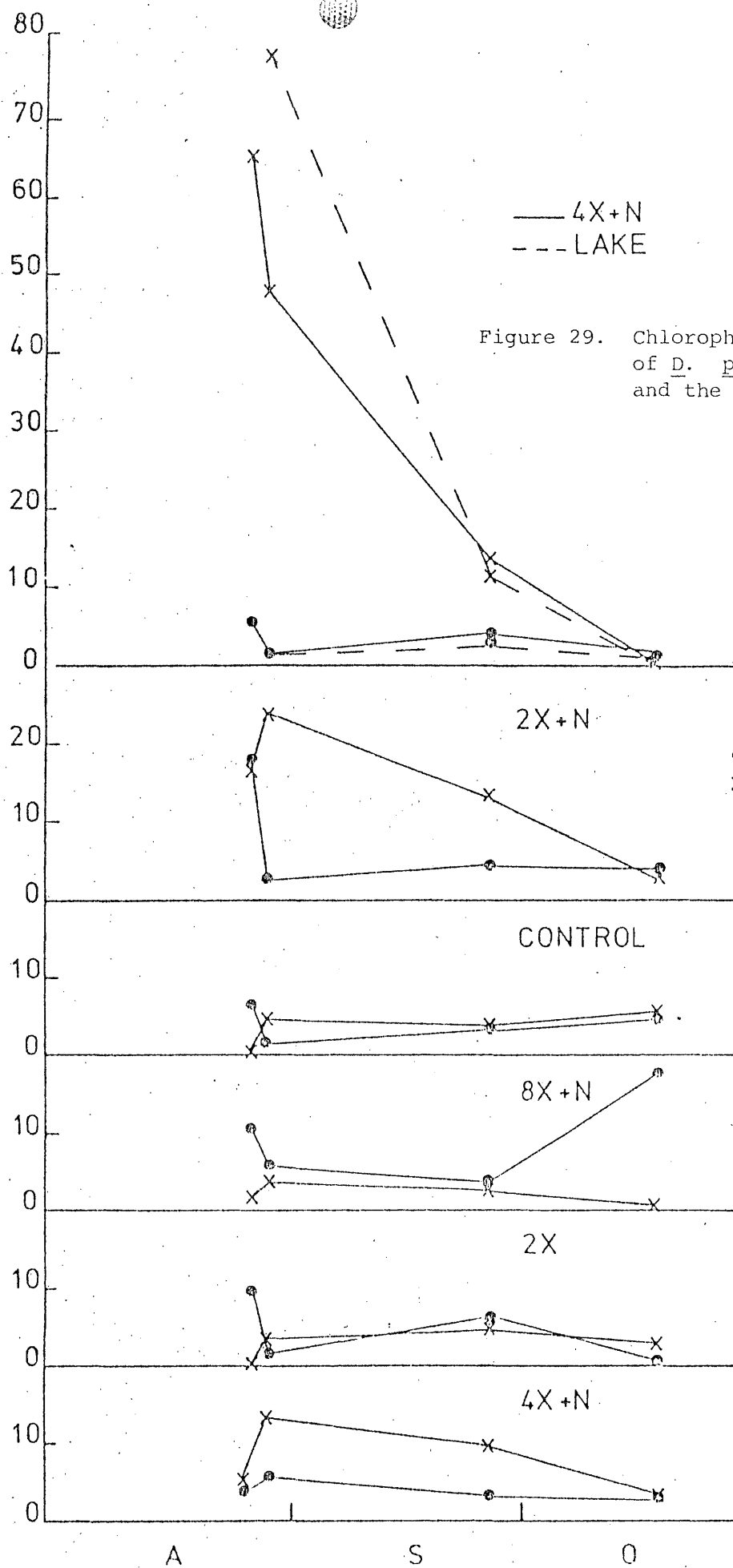


Figure 28. Scatter diagram showing the regression between chlorophyll a concentrations and Daphnia.



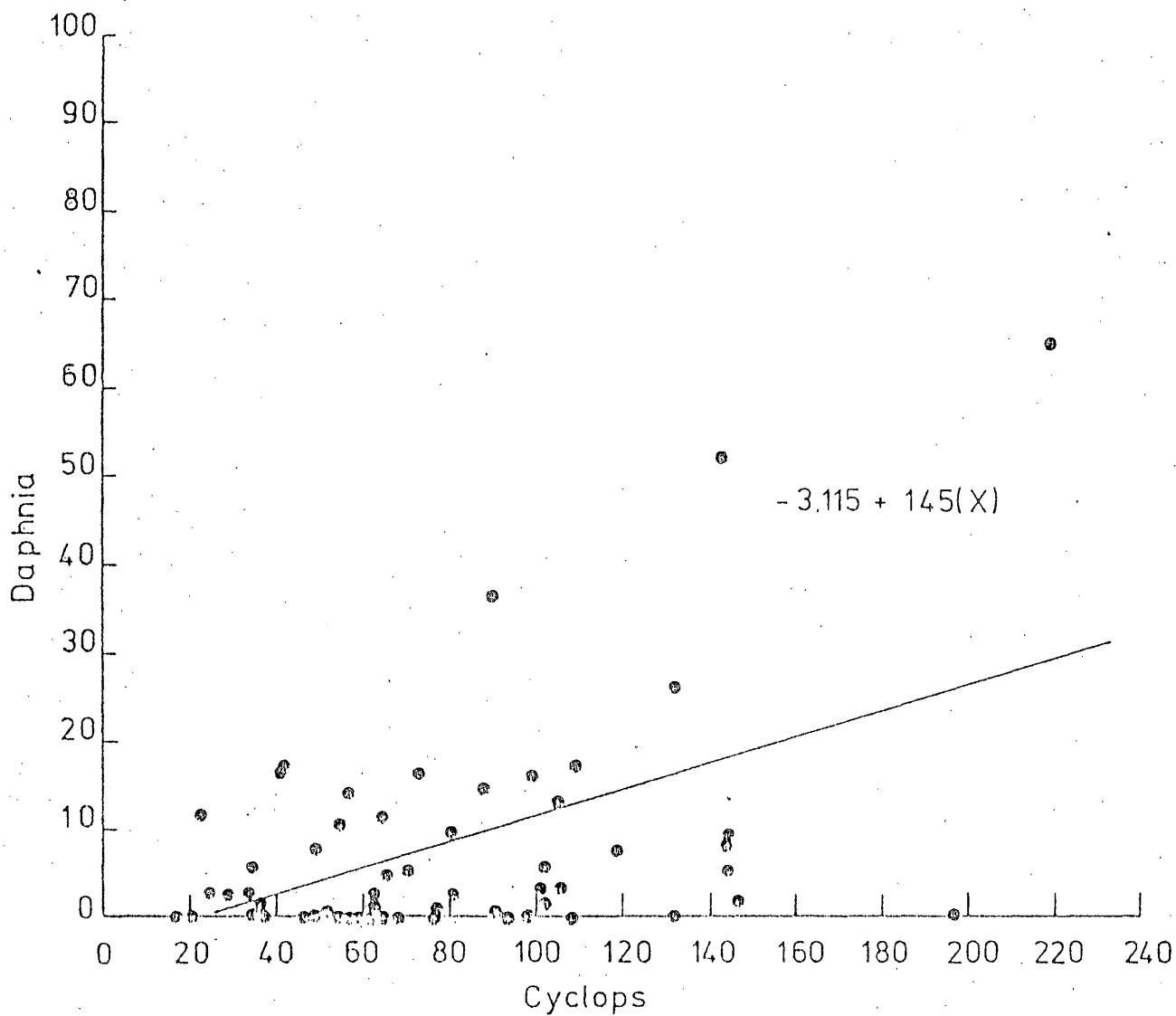


Figure 30. Scatter diagram showing the correlation between C. bicuspidatus thomasi and D. pulex. The points represent pooled data from all the microcosms and the lake.

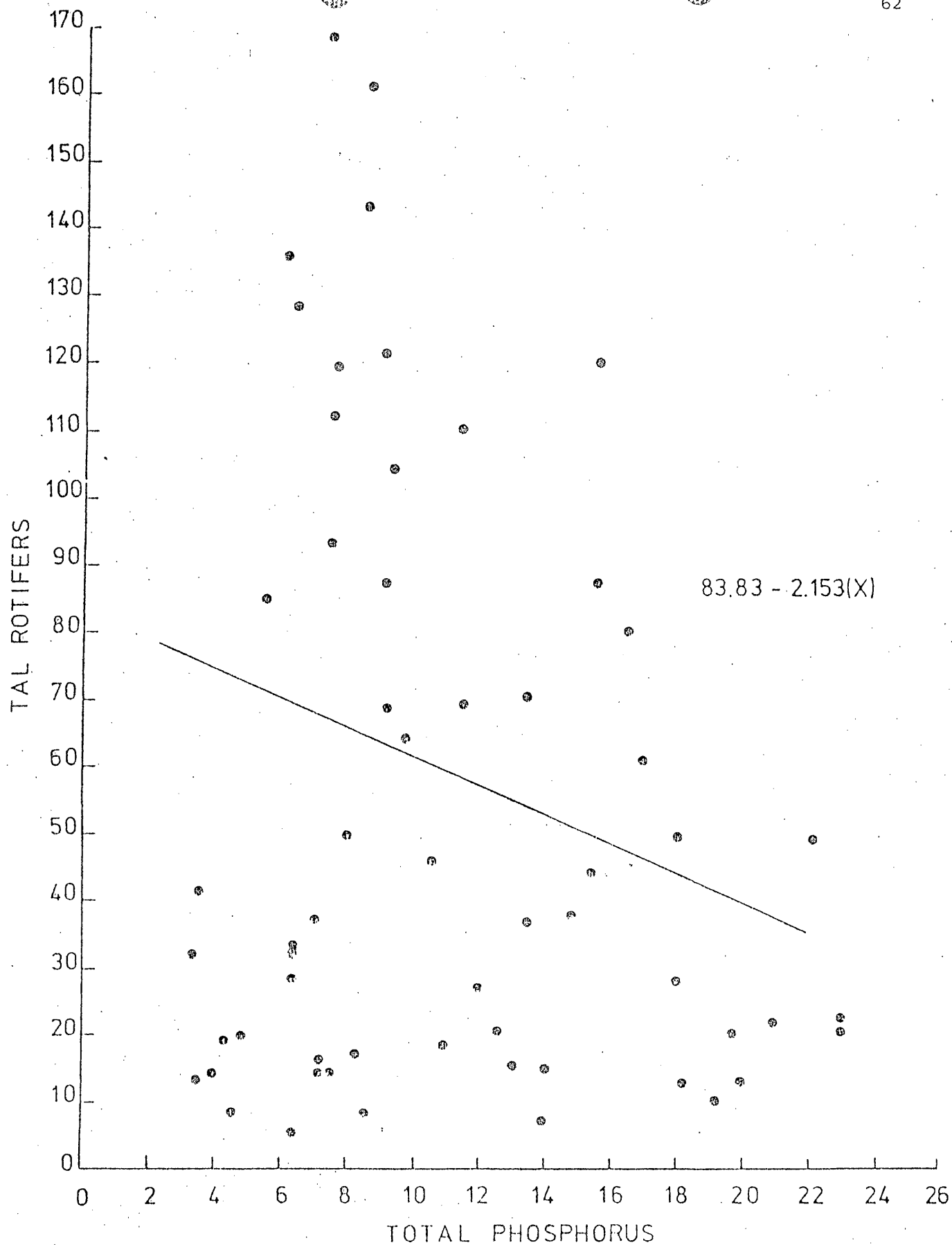


Figure 31. The regression results between total phosphorus and total rotifers. The data are pooled from all microcosms and the lake.

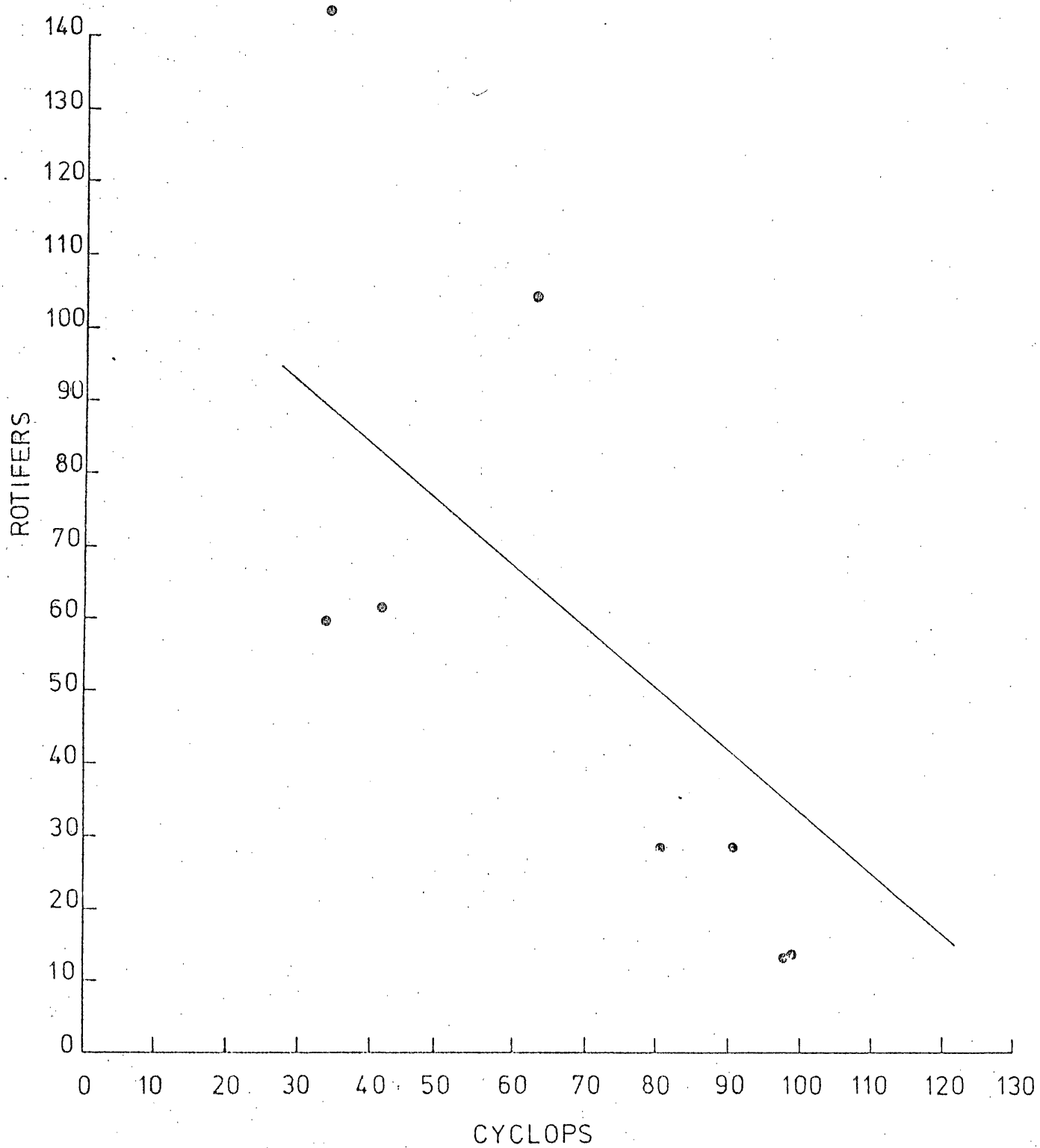


Figure 32. Results of the regression between total rotifers and C. bicuspidatus thomasi.

predation but again, as with D. pulex, death rates might be more important than population numbers.

Trophic State Index (TSI)

The trophic state index (TSI) is numbers between 0 and 100 (Carlson, 1977). An increase in the value of the TSI by ten (e.g., 0 to 10) represents a doubling of algal biomass. Carlson suggests a TSI of 40 as the division between mesotrophic and oligotrophic lakes, 50 as the division between mesotrophic and meso-eutrophic, and 60 as the division between meso-eutrophic and eutrophic. The TSI can be calculated from Secchi disc, total phosphorus and chlorophyll data. The average TSI values for the study period for Big Brooklyn Lake are presented in Table 5. Note that the TSI values tend to increase as loading increases. Also, there is a suggestion that phosphorus plus nitrate increased TSI values more than phosphorus alone (Figure 33).

We tested to determine if the three TSI values (i.e., based on Secchi disc, total phosphorus and chlorophyll) for any microcosm were significantly different from each other. With two exceptions the TSI values were not significantly different. The exceptions occurred in the 4X+N treatment ($TSI:CHL > TSI:SD, \alpha \leq 0.05$).

We also compared TSI's between the microcosms. The TSI's for 8X+N were significantly greater (Lake, Control, 2X+N and 4X, $\alpha = .2$) than the TSI's in all but the 4X+N treatment. Microcosm 4X+N had TSI's significantly larger than the lake ($\alpha = .02$), 2X ($\alpha = .2$) and 4X ($\alpha = .1$), while those of microcosm 4X were significantly greater than those of the lake ($\alpha = .02$). Thus, these statistical analyses support our statement that the TSI's increased with increased loading. In fact the loading appears to have changed the trophic state of the 2X and the 2X+N microcosms

Table 5. Average trophic state index values for Big Brooklyn Lake
(SD = Secchi disc, TP = total phosphorus and CHL =
chlorophyll a).

Microcosm	TSI SD	TSI (TP)	TSI (CHL)
Lake	36	36	37
Control	39	35	43
2X	39	37	37
2X+N	38	38	47
4X	38	39	40
4X+N	40	40	43
8X+N	40	44	51

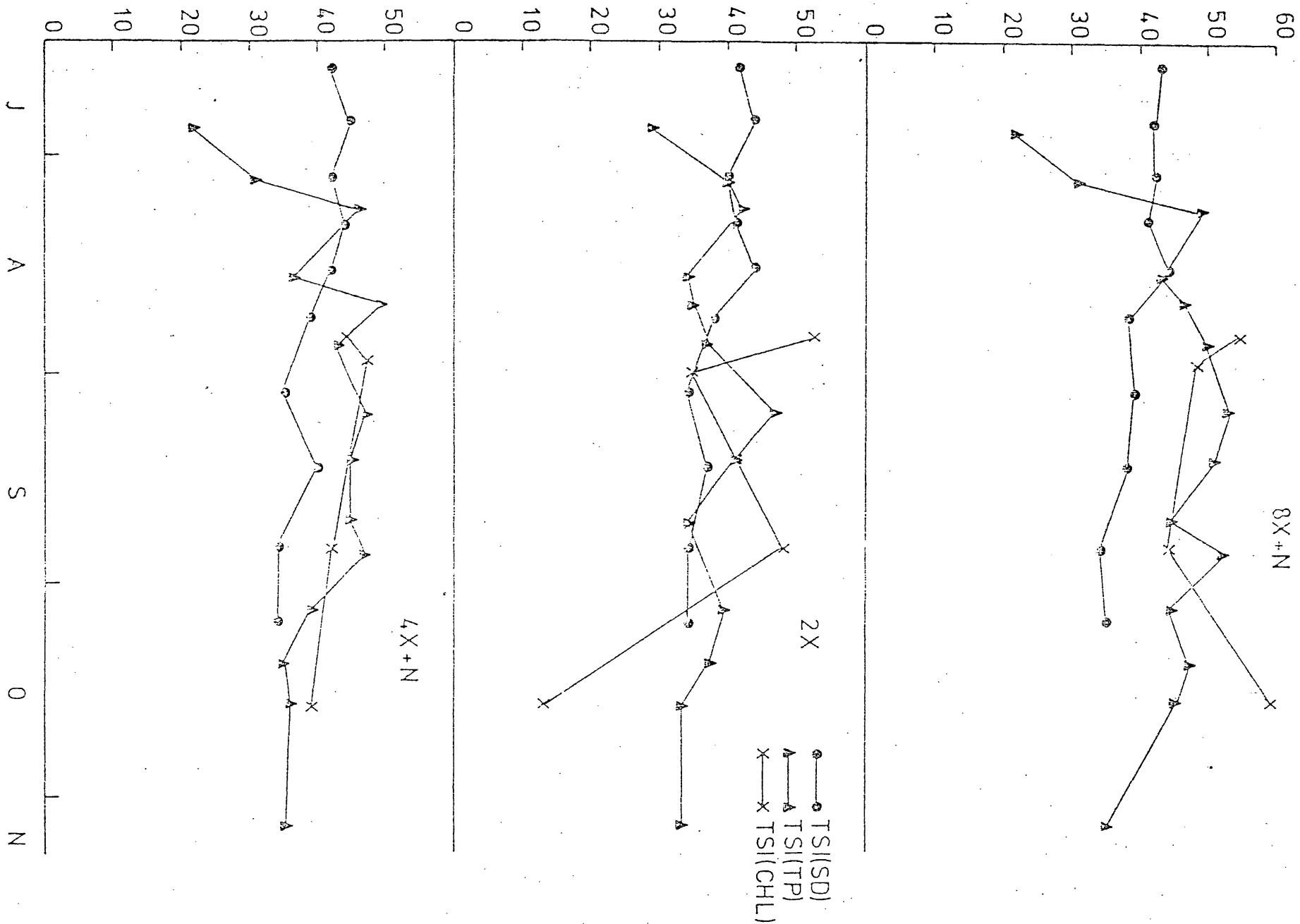


Figure 33. The ordinate represents values of the TSI. Data are presented for all the microcosms and the lake. Abbreviations indicate data used to calculate the TSI: Chl, chlorophyll; SD, Secchi dis; TP, total phosphorus. Data were collected from July to november 1978.

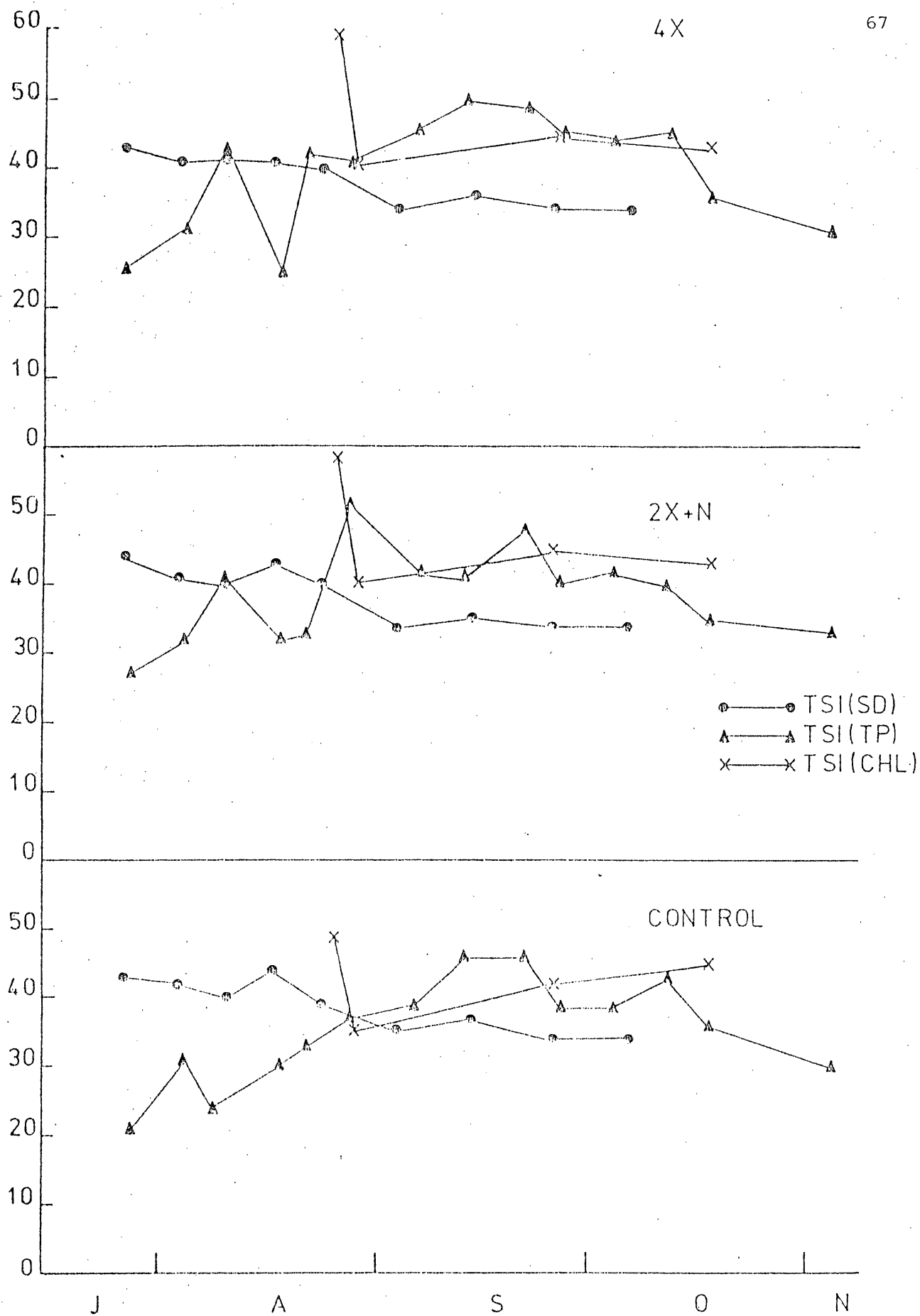


Figure 33. (Continued)

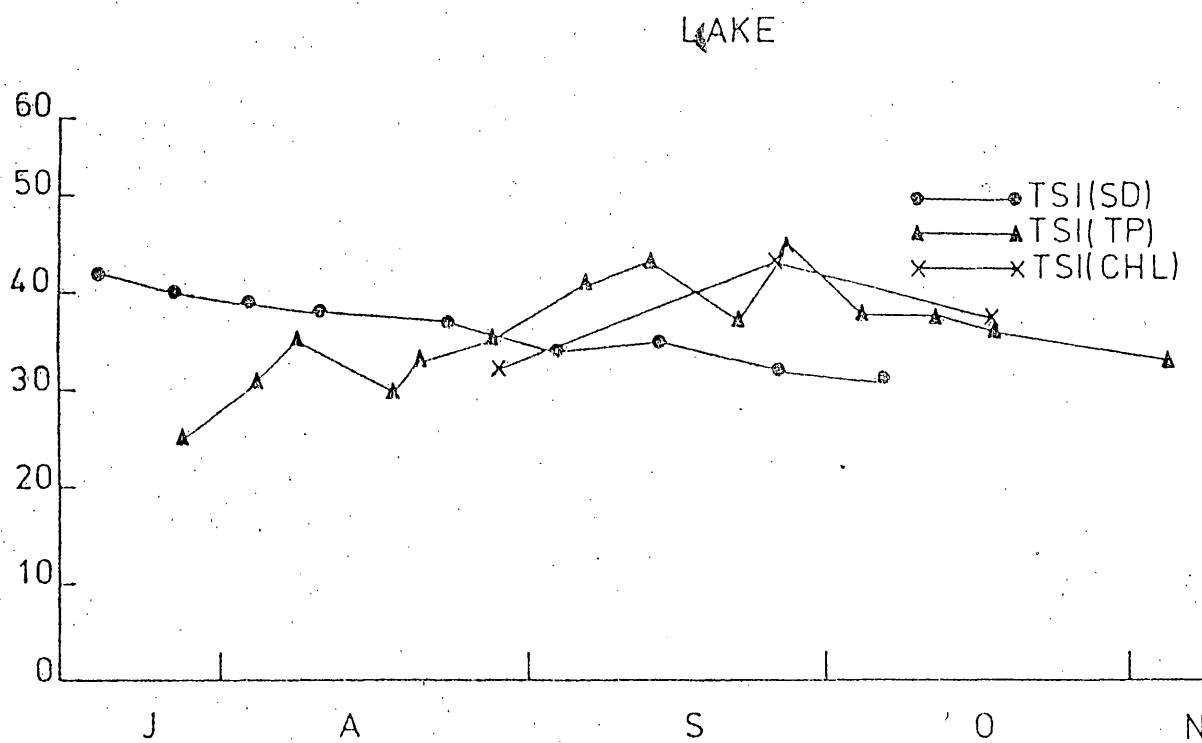


Figure 33. (Continued)

from oligotrophic to barely mesotrophic, and microcosm 8X+N and 4X+N definitely became mesotrophic.

The Study Objectives

The first objective of this project was to determine changes in the dominant phytoplankton species resulting from changes in phosphorus loading. The phytoplankton samples have not yet been enumerated. However, as already pointed out there were indications of an increase in algal standing crop in the microcosms receiving the greater nutrient load (i.e., increased dissolved oxygen, decreased carbon dioxide, increased chlorophyll a and larger attenuation coefficients).

The second objective was to determine the effect of altered algal species composition on the species and numbers of zooplankton. We are especially interested in cladocerans, which are important as fish food. Some trends and statistically significant differences were noted in the data on zooplankton populations. However, we again are unable to critically evaluate the objective until additional data are available. In particular we need more information on zooplankton population dynamics, which we can obtain in part by the egg ratio method for evaluating $r=b-d$ (where b and d are the instantaneous birth and death rates; Edmondson, 1960). These same data are required to complete the third objective, which is to infer the effects on trout production resulting from any change in zooplankton productivity.

SUMMARY

Several significant differences and correlations between the population sizes of zooplankton taxa and other parameters were observed. However, these observations cannot be critically interpreted until additional data from phytoplankton enumerations and on zooplankton population dynamics are available. These data are also required before we can meaningfully complete our objectives. Hence, at present data are not yet available to evaluate our null hypothesis that a change in water quality will not affect the recreational or land use values of lakes and watersheds in the Snowy Mountain Range of the Medicine Bow National Forest.

Big Brooklyn Lake is an oligotrophic lake, low in calcium and magnesium ions, low in alkalinity and low in conductivity. Six one meter by six meter microcosms were placed in the lake, and each received a different loading of phosphorus or phosphorus plus nitrogen.

Data that suggests microcosms receiving greater nutrient loads had larger standing crops were those on: dissolved oxygen, carbon dioxide, Secchi disc readings, attenuation coefficients, chlorophyll a, and, several Trophic State Indices (TSI). The latter data also indicate an increase in loading of about four times the present load would shift the lake to a mesotrophic state.

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APPENDIX A

Water temperature, in °C, of Big Brooklyn Lake on various sampling dates in 1978.

19 July 1978

<u>Depth</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
Sur	11.1	11.5	11.3				11.2
1m	11.1	11.4	11.2				11.2
2m	11.0	11.3	11.2				11.0
3m	10.8	11.0	10.9				10.8
4m	9.3	10.1	10.1				9.0
5m	7.8	9.6	9.8				7.4
6m	6.3	7.8					6.3
7m							5.6
8m							5.3
9m							5.3
10m							

27 July 1978

Sur	14.8	14.4	14.6	14.5	14.4	14.4	14.2
1m	13.9	13.8	14.0	14.0	14.1	13.9	14.0
2m	13.4	13.3	13.4	13.4	13.3	13.3	13.4
3m	12.4	12.4	12.5	12.5	12.5	12.5	12.4
4m	11.2	11.4	11.4	11.4	11.4	11.3	11.3
5m	9.2	9.4	9.6	9.3	9.4	9.2	10.2
6m	7.2	7.4	7.3	8.6	7.0	7.2	6.8
7m							5.8
8m							5.4
9m							5.1
10m							4.9
							4.8

3 August 1978

Sur	14.6	14.4	14.4	14.5	14.5	14.6	14.6
1m	14.3	14.2	14.2	14.2	14.3	14.4	14.5
2m	13.8	13.9	13.8	14.0	14.0	14.1	14.2
3m	13.2	13.1	13.1	13.1	13.1	13.1	12.9
4m	12.3	12.1	12.2	12.3	12.4	12.3	12.4
5m	10.4	10.5	10.1	10.3	10.2	10.1	10.8
6m	8.2	8.8		10.1	8.1	7.6	7.6
7m							6.1
8m							5.4
9m							5.2
10m							5.0
11m							4.8
12m							4.8

APPENDIX A (Continued)

<u>Depth</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
<u>10 August 1978</u>							
Sur	14.6	14.8	14.7	14.6	14.7	14.6	14.5
1m	14.3	14.3	14.3	14.3	14.35	14.3	14.5
2m	14.1	14.1	14.1	14.1	14.1	14.1	14.3
3m	13.5	13.5	13.5	13.5	13.5	13.5	13.5
4m	12.8	12.9	12.8	12.8	12.9	12.9	13.1
5m	10.5	11.1	10.5	10.8	10.7	10.7	10.9
6m	8.3	8.5	9.0	9.8	8.2	8.4	8.1
7m							6.1
8m							5.5
9m							5.3
10m							5.2
11m							5.1
12m							5.1
<u>17 August 1978</u>							
Sur	10.5	10.5	10.5	10.5	10.6	10.5	10.5
1m	10.5	10.5	10.5	10.5	10.4	10.5	10.5
2m	10.3	10.3	10.3	10.3	10.4	10.3	10.5
3m	10.3	10.3	10.3	10.3	10.3	10.3	10.5
4m	10.2	10.3	10.3	10.3	10.3	10.3	10.3
5m	10.1	10.2	10.2	10.3	9.9	10.2	10.3
6m	10.1	10.1	10.2	10.2	9.9	10.2	10.3
7m							10.1
8m							9.8
9m							9.5
10m							8.3
<u>24 August 1978</u>							
Sur	11.9	11.6	11.5	11.8	11.6	11.58	11.7
1m	11.4	11.59	11.5	11.5	11.5	11.4	11.6
2m	11.3	10.4	11.3	11.3	11.4	11.3	11.5
3m	11.2	11.3	11.2	11.2	11.2	11.2	11.4
4m	11.0	11.1	11.0	11.1	11.1	11.1	11.0
5m	10.8	10.9	10.8	10.8	10.9	10.8	10.8
6m	10.6	10.8	10.7	10.8	10.6	10.7	10.6
7m							10.3
8m							9.6
9m							8.8
10m							
<u>3 September 1978</u>							
Sur	12.4	12.5	12.5	12.3	12.4	12.5	12.3
1m	12.3	12.2	12.3	12.3	12.3	12.2	12.1
2m	12.1	12.1	12.1	12.1	12.1	12.1	11.9
3m	12.0	11.9	12.0	12.0	12.0	12.0	11.9
4m	11.9	11.7	11.8	11.7	11.8	11.8	11.7
5m	11.6	11.5	11.7	11.6	11.6	11.6	11.5
6m	11.5	11.5	11.4	11.6	11.5	11.5	11.3
7m							11.1
8m							10.9
9m							9.6
10m							9.0

APPENDIX A (Continued)

<u>Depth</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
<u>14 September 1978</u>							
Sur	9.4	9.4	9.3	9.3	9.3	9.3	9.2
1m	9.3	9.3	9.3	9.3	9.2	9.2	9.2
2m	9.1	9.2	9.2	9.2	9.1	9.1	9.1
3m	9.0	9.1	9.1	9.1	9.1	9.1	9.0
4m	9.0	9.1	9.0	9.1	9.0	9.0	9.0
5m	9.0	9.0	9.0	9.0	8.9	8.9	9.0
6m	8.9	9.0	9.0	9.0	8.9	8.9	9.0
7m							8.9
8m							8.7
9m							8.6
10m							8.5
11m							8.5
<u>26 September 1978</u>							
Sur	6.8	6.9	6.8	6.9	7.0	7.0	6.8
1m	6.7	6.6	6.7	6.6	6.7	6.7	6.6
2m	6.5	6.5	6.5	6.5	6.6	6.7	6.5
3m	6.5	6.3	6.4	6.4	6.5	6.5	6.5
4m	6.3	6.3	6.3	6.3	6.3	6.3	6.3
5m	6.2	6.1	6.1	6.2	6.1	6.1	6.1
6m	5.9	5.9	6.1	6.1	5.9	5.9	5.9
7m							5.7
8m							5.7
9m							5.7
10m							5.7
<u>6 October 1978</u>							
Sur	5.5	5.4	5.5	5.3	5.4	5.3	5.4
1m	5.5	5.3	5.3	5.3	5.4	5.3	5.4
2m	5.4	5.3	5.3	5.2	5.3	5.3	5.4
3m	5.3	5.2	5.1	5.1	5.3	5.2	5.4
4m	5.2	5.1	5.1	5.1	5.2	5.1	5.4
5m	5.2	5.1	5.0	5.0	5.1	5.1	5.3
6m	5.2	5.1	5.0	5.0	5.1	5.1	5.2
7m							5.2
8m							5.2
9m							5.2
10m							5.2
11m							5.2
12m							

APPENDIX B

Data are the depth (m) at which the Secchi disc could no longer be seen in Big Brooklyn Lake. Sampling was done in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8x+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
19 July	3.5	3.5	3.25				3.5
27 July	2.90	3.0	3.5	3.25	3.10	3.25	4.0
3 August	3.5	4.1	3.4	3.5	3.75	3.75	4.25
10 August	3.1	3.75	3.75	4.1	4.0	3.75	
17 August	3.5	3.0	3.0	3.0	3.25	3.75	
24 August	4.5	4.6	4.5	4.2	4.0	4.1	5.1
3 September	5.5	6.0	4.25	5.5	6.1	6.0	6.25
14 September	4.0	5.0	4.75	5.0	5.75	5.25	5.75
26 September	6.25	6.0	6.0	6.0	6.0	6.25	7.25
6 October	6.0	6.0	5.75	6.0	6.0	6.0	7.25

APPENDIX C

Data are the mg CaCO_3 found in the microcosms and Big Brooklyn Lake on various sampling dates in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
30 July	14.8	16.4	14.49	14.14	25.3	14.83	30.82
7 August	14.95	14.95	14.26	13.91	15.64	14.84	14.84
22 August	21.85	21.16	32.20	21.965	22.08	21.85	21.62
28 August	22.885	21.62	21.62	22.54	20.355	21.045	18.86
26 September	19.78	20.47	23.00	22.08	24.84	23.115	24.035

APPENDIX D

The pH values for the microcosms and Big Brooklyn Lake on various sampling dates in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
28 July	7.25	7.37	7.3	7.1	7.2	7.3	7.1
3 August	7.8	7.8	7.75	7.7	7.55	7.75	7.5
7 August	7.4	7.4	7.4	7.4	7.4	7.4	7.4
18 August	7.3	7.45	7.6	7.45	7.4	7.4	7.45
22 August	7.8	7.59	8.2	7.8	7.75	7.69	7.8
28 August	7.65	7.5	7.7	7.5	7.65	7.5	7.7
26 September	7.75	7.65	8.05	7.7	7.7	7.7	7.65
13 October	7.55	7.51	7.55	7.59	7.59	7.58	7.55
4 November	7.75	8.05	7.7	7.85	8.25	7.75	7.65

APPENDIX E

Data for dissolved carbon dioxide (ppm) in the microcosms and Big Brooklyn Lake on various sampling dates in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
27 July	2.208	1.856	1.93	2.979	4.234	1.972	6.494
7 August	1.579	1.579	1.506	1.469	1.652	1.567	1.567
22 August	.995	1.562	.584	1.000	1.128	1.128	.984
28 August	1.471	1.964	1.239	2.047	1.309	1.911	1.213
26 September	1.102	1.436	.642	1.380	1.553	1.445	1.686

APPENDIX F

Data for dissolved oxygen in the microcosms and Big Brooklyn Lake for various sampling periods in 1978.

Date	4X+N		2X		8X+N		Control		2X+N		4X		Lake	
	Sur	4m	Sur	4m	Sur	4m	Sur	4m	Sur	4m	Sur	4m	Sur	4m
28 July	7.8	8.3	8.0	8.6	7.9	8.1	7.9	8.0	8.0	8.4	7.9	8.5	7.9	7.9
29 July	7.8	8.3	8.0	8.6	7.9	8.1	7.9	8.0	8.0	8.4	7.9	8.5	7.9	8.3
7 August	8.1	8.9	8.0	9.4	7.8	8.9	7.9	9.4	7.9	9.2	7.8	9.1	7.9	7.5
22 August	9.5	8.1	7.9	8.5	8.1	9.1	8.0	10.0	6.2	8.3	8.0	8.0	8.1	10.3
29 August	9.1	8.6	8.3	8.3	10.3	9.6	8.2	8.1	8.8	8.5	8.2	7.9	8.4	8.3
13 Sept	7.7	7.7	7.8	7.3	8.7	8.5	7.9	7.8	7.3	8.1	7.5	7.6	7.8	7.3
13 Oct	7.8		8.3	8.3	10.3	8.5	9.0	7.8	8.3	9.1	7.2	8.7	9.1	10.3

APPENDIX G

Conductivity values in the microcosms and Big Brooklyn Lake for various sampling periods in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8x+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
3 August	36	34	34	33	33	33	34
7 August	32	34	31	31	31	31	31
22 August	56	46	44	44	43	44	44
28 August	47	38	36	34	38	44	43
26 September	50	41	39	37	36	36	36
13 October	47	47	45	36	40	40	41
4 November	36	36	36	37	44	43	36

APPENDIX H

Data on the concentration (ppb) of fine fractions of phosphorus found in the water of Big Brooklyn Lake in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
<u>Fraction: Total Filterable and Nonfilterable Phosphate (Total Phosphorus)</u>							
28 July	3.5	5.5	3.5	3.3	4.8	4.5	4.3
4 August	6.4	12.0	6.4	6.4	7.0	6.4	6.4
8 August	18.0	14.0	23.0	4.0	13.0	14.8	8.6
18 August	8.8	8.0	15.0	6.1	6.8	4.3	6.0
22 August	23.0	8.3	19.2	7.2	7.5	13.4	7.2
28 August	15.2	9.5	24.1	9.5	25.4	12.9	8.4
6 September	20.0	19.7	30.3	-10.9	14.0	18.3	12.5
13 September	16.5	13.2	25.4	18.4	13.0	24.2	15.0
22 September	16.9	8.0	15.4	18.0	20.9	22.1	9.7
27 September	18.8	9.0	27.6	11.2	12.0	16.5	16.4
4 October	11.3	11.5	15.6	11.4	13.4	15.5	10.6
12 October	8.6	9.7	19.6	14.8	12.1	17.1	10.6
18 October	9.3	7.5	16.5	9.1	8.6	9.1	9.2
4 November	8.5	7.3	8.3	6.1	7.6	6.4	7.4

Fraction: Dissolved Filterable Orthophosphate (Ortho-phosphorus)

28 July	0.5	0.5	0.5	0.5	0.5	0.5	0.5
4 August	0.8	0.8	0.6	0.8	0.9	0.8	0.8
8 August	6.5	1.7	0.0	7.1	2.2	4.8	1.0
18 August	4.8	1.8	15.0	0.9	1.5	3.8	1.3
22 August	3.0	1.5	7.4	2.1	1.3	1.8	0.5
28 August	8.8	3.2	12.8	2.8	2.6	7.0	2.3
6 September	2.5	0.3	7.3	0.5	1.2	5.0	0.7
13 September	1.5	1.3	7.3	1.2	1.2	2.8	2.1
22 September	1.3	1.2	1.6	.7	.7	1.0	0.8
27 September	3.3	0.5	12.0	1.4	2.5	6.0	0.1
4 October	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12 October	1.0	1.0	1.1	1.1	1.1	1.2	1.5
18 October	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 November	1.6	1.2	1.0	1.2	1.2	1.2	1.2

Fraction: Total Filterable and Nonfilterable Orthophosphate

28 July	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 August	1.0	1.2	1.0	0.8	0.6	0.7	0.6
8 August	5.5	6.2	0.0	2.5	2.6	5.9	1.8
18 August	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22 August	5.7	5.0	11.2	3.5	3.7	5.9	2.9
28 August	4.2	2.6	11.9	1.4	1.8	6.0	0.5
6 September	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13 September	3.7	2.6	8.2	1.8	2.3	4.0	2.3
22 September	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 September	5.5	1.4	14.9	1.2	2.9	7.2	1.2
4 October	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12 October	1.3	1.5	2.3	2.1	1.7	1.3	2.1
18 October	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 November	1.7	2.0	1.1	1.7	1.7	1.6	1.9

APPENDIX H (Continued)

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
<u>Fraction: Total Filterable Phosphate</u>							
28 July	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 August	2.4	3.2	1.2	2.2	0.0	2.2	1.8
8 August	5.0	5.8	0.0	3.0	3.6	8.0	6.4
18 August	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22 August	6.8	4.8	0.8	0.3	4.0	6.0	4.8
28 August	7.2	3.8	15.8	4.0	4.5	7.7	9.0
6 September	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13 September	14.0	6.2	11.2	7.6	11.2	22.2	7.5
22 September	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27 September	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 October	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12 October	3.4	5.8	5.2	3.3	2.5	4.0	3.0
18 October	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4 November	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Fraction: Total Nonfilterable Phosphate (Nonfilterable phosphorus)

4 August	4.0	8.8	5.2	4.2	--	4.2	4.6
8 August	13.0	8.2	--	1.0	9.4	6.8	2.2
22 August	16.2	3.5	18.4	6.9	3.5	7.4	2.4
28 August	8.0	5.7	8.3	5.5	20.9	5.2	0.0
13 September	2.5	7.0	14.2	10.8	1.8	2.0	7.5
12 October	5.2	3.9	14.4	11.5	9.6	13.1	7.5

APPENDIX I

Data for nitrate-nitrogen (ppb) in the microcosms and Big Brooklyn Lake for various sampling periods in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
4 August	1.0	6.2	0.0	3.0	2.0	0.0	0.0
18 August	170.94	11.5	5.0	155.94	37.0	7.5	18.0
28 August	24.2	8.3	69.8	8.0	4.9	1.8	0.38
11 September	56.35	2.8	103.7	0.0	17.6	4.2	0.0
22 September	3.3	1.4	3.0	0.0	0.7	0.55	0.55
26 September	9.36	1.41	38.7	10.4	9.0	3.8	0.4
3 October	3.14	0.0	12.8	1.1	0.0	0.0	--
13 October	1.41	2.10	2.10	1.41	0.7	0.7	1.41
4 November	2.45	0.0	1.1	1.1	2.45	11.43	1.41

APPENDIX J

Data for ammonia-nitrogen (ppb) in the microcosms and Big Brooklyn Lake for various sampling dates in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
4 August	114.31	74.03	0.2	69.2	0.2	24.8	9.15
24 August	4.67	.2	0.0	69.2	0.2	0.2	6.92
28 August	0.0	11.39	0.0	9.15	0.0	0.0	0.0
10 September	0.2	0.2	0.2	0.2	2.44	4.67	0.0
22 September	0.0	0.0	0.0	0.0	2.44	0.0	0.0
26 September	4.67	4.67	9.15	4.67	9.15	9.15	6.92
13 October	0.0	6.92	0.2	9.15	0.2	4.67	9.15
4 November	11.39	0.2	0.0	6.92	0.0	0.0	13.62

APPENDIX K

Chlorophyll data in mg/l for the microcosms and Big Brooklyn on various sampling dates in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
<u>Chlorophyll A</u>							
26 August	3.7633	9.58289	10.4662	6.56657	17.7626	5.16493	
29 August	5.6039	1.47398	5.9426	1.6040	2.5040	1.5630	1.1620
26 September	3.3566	6.13366	3.81644	3.1868	4.1688	4.0356	3.5115
18 October	2.3943	.1709	17.8568	4.5091	3.6752	1.7628	1.8266
<u>Chlorophyll B</u>							
26 August	.4946	1.6005	2.11973	.88140		5.43312	
29 August	.7137	.62985	2.1999	.5236	1.3751	.7333	.6024
26 September	.4864	.04132	.835705	.8572	1.0261	.8346	1.02936
18 October	.6833	.22482	.3165	.7934	.09788	.7191	.0465
<u>Chlorophyll C</u>							
26 August	3.859		.5871	27.31906		103.4319	
29 August						1.11829	
26 September	.6748	1.4265					
18 October	3.0245		10.9574		2.8779	2.5552	12.9351

APPENDIX L

Attenuation coefficients in the microcosm and Big Brooklyn Lake on various sampling dates in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
3 August	.389	.329	.4106	.362	.443	.4506	.4840
17 August	.6826	.4985	.604	.446	.683	.521	.7030
28 August	.398	.4578	.4618	.405	.443	.453	.464
14 September	.522	.463	.687	.377	.450	.498	.554
6 October	.492	.470	.448	.557	.517	.530	.50533

APPENDIX M

Number of Cyclops bicuspidatus thomasi per liter in the microcosms and Big Brooklyn Lake for various sampling periods in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
27 July	98.3	93.5	77.0	65.6	65.7	62.9	81.0
3 August	90.7	52.8	77.8	36.7	108.4	106.2	422.53
11 August	80.9	63	144.0	102.5	101.1	88.3	143.8
24 August	145.7	132.2	147	197.3	130	219.6	223.6
4 September	99.2	145.2	118.6	115.2	90.1	109.6	132.1
22 September	41.9	55.1	49.9	57.5	42.5	23.3	29.8
3 October	34	25.1	37.8	102	65.2	56.7	73.1
17 October	63.3	63.3	48.9	71.2	34	23.3	17.2
3 November	34.5	59.5	51.8	20.7	46	68	23.6

APPENDIX N

Number of Daphnia pulex per liter in the microcosms and Big Brooklyn Lake for various sampling periods in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
27 July							9.5
3 August	0.8	.7	1.0	1.7		3.3	29.4
11 August	2.9	1.1	8.0	1.7	3.3	14.7	54.2
24 August	5.1		1.5		16.3	65.1	108.3
4 September	27.2	9.3	7.7	13.2	36.4	17	26.1
22 September	16.8	10.5	7.9		17	11.7	2.7
3 October	5.7	2.8		5.7	11.3	14.2	16.3
17 October	2.8	2.9		5.1	2.8		
3 November							

APPENDIX O

Number of Chydorinae per liter in the microcosms and Big Brooklyn Lake for various sampling periods in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
27 July							
3 August							
11 August							2.6
24 August	1.9						
4 September		1.9		3.7			
22 September				10	2.8	2.9	2.7
3 October	11.3	8.4	55.5		2.8	25.5	
12 October	30.3	2.9	14.4	5.1	5.8	12.5	
3 November	5.8	8.5	8.6		8.1		

APPENDIX P

Number of Polyarthra per liter in the microcosms and in Big Brooklyn Lake for various sampling periods in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
27 July	13.1	68	30	16.4	5.7	5.7	19.1
3 August	19.6	14.6	28.2	4.2	23.1	27.1	36.8
11 August	10.8	4.4	13.3	11.7	12.2	29.4	8.3
24 August	7.7	5.7	4.5	3.7	5.4	16.8	4.2
4 September		1.9			1.9	3.8	3.7
22 September	22.3	15.8	5.3	17.5	14.2	17.5	19.0
3 October	22.7	33.5	25.2	53.8	28.3	45.3	16.3
17 October	66	54.6	48.9	76.3	90.7	72.9	66.1
3 November	43.1	62.3	172.5	100.6	94.8	223.8	149.6

APPENDIX Q

Number of Keratella cochlearis per liter in the microcosms and Big Brooklyn for various sampling periods in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
27 July		17	11.7	14.6	14.3	2.9	
3 August	4.4	10.4	3.9	1.1	10.7	1.1	
11 August	13	0.8	6.7	1.7	3.3	7.4	
24 August	1.3	1.9	3	7.4	1.8	5.6	6.9
4 September	5.8	9.3	5.8	11.3	3.8	7.5	11.2
22 September	22.3	15.8	31.5	22.5		26.3	24.2
3 October	25.5	19.5	37.8	39.7	25.5	28.3	19
17 October	30.3	46	25.9	30.5	39.7	14.6	2.9
3 November	11.5	8.5	17.3	26.6	16.3	39.7	10.5

APPENDIX R

Number of Keratella quadrata per liter in the microcosm and Big Brooklyn Lake for various sampling periods in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
27 July							
3 August	4.4				1.8	2.2	86.9
11 August	1.4	0.5					
24 August	2.6	1.9				1.9	
4 September			1.9		1.9		
22 September				2.5			5.4
3 October				2.8			
17 October			5.8				
3 November							

APPENDIX S

Number of Kellicottia longspina per liter in the microcosms and Big Brooklyn Lake for various sampling periods in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
27 July				1.4			
3 August		2.1			1.8	3.3	4.4
11 August	.7	1.4	1.3	.8		1.5	
24 August	2.6	7.6	3	3.7	7.2	13.0	5.6
4 September	1.9	7.4	1.9	1.9	7.7	1.9	5.6
22 September	14	15.8	7.9		8.5	5.8	8.1
3 October	5.7	2.8	5.6	8.5	17	11.3	10.8
17 October	8.3	8.6		10.2	22.7		
3 November		2.8		5.9	8.1		

APPENDIX T

Number of rotifers per liter in the microcosms and Big Brooklyn Lake for various sampling points.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
22 July							
3 August							
11 August	2.8						
24 August	8.9						
4 September	5.8	1.9	13.6	5.7			
22 September	2.8	2.6		7.5			8.1
3 October	5.7	13.9	52.9	5.2		2.8	
17 October	8.3	2.9	5.8		2.8	14.5	2.9
3 November		2.8					

APPENDIX U

Number of total rotifers per liter in the microcosm and Big Brooklyn Lake for various sampling periods in 1978.

<u>Date</u>	<u>4X+N</u>	<u>2X</u>	<u>8X+N</u>	<u>Control</u>	<u>2X+N</u>	<u>4X</u>	<u>Lake</u>
27 July	13.1	85	41.7	32.4	20	86	19.1
3 August	28.4	27.1	32.1	5.3	37.4	33.7	128.1
11 August	28.7	7.1	21.3	14.2	15.5	38.3	8.3
24 August	23.1	17.1	10.5	14.8	14.4	37.3	16.7
4 September	13.5	20.5	23.2	18.9	15.3	13.2	20.5
22 September	61.4	50	44.7	50	22.7	49.6	64.8
3 October	59.6	69.7	120.9	110.5	70.8	87.7	46.1
17 October	104.6	112	80.6	122.9	161.2	87.5	69
3 November	143.4	93.5	215.7	136.1	119.3	300.7	168.3

Arizona Climatological Data

1960-1961

Arizona
Monthly
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